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ASTRONOMICAL GEOLOGY.

ASTRONOMICAL GEOLOGY:

A TREATISE

RESPECTING THE CAUSES TO WHICH THE STRUCTURAL AND SUPERFICIAL CONFIGURATION OF THE EARTH'S CRUST IS ATTRIBUTABLE.

By R. G. M. BROWNE.

"I will dry up her sea and make her springs dry."—Jer. li. 36.

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PREFACE.

THE following Treatise is intended for an analysis of the various circumstances appearing to bear upon the subject of Geology. It has been attempted with the view of ascertaining the causes which have produced the structural and superficial configuration of the earth's crust, and especially of that part of it which comprises the aqueous rocks.

The Author's aim being limited to an endeavour to elicit the general principles into which the inquiry is resolvable, he has abstained from introducing many geological details which might be referred to in support of the theory he advances.

That theory, and some of the minor conclusions upon which it is founded, he believes to be new; and although they are not quite coincident with opinions expressed in more extensive and more erudite works, yet in venturing to publish them he is conscious that he is not acting inconsistently with the respect and deference that are due to those who are leading authorities in the matters he has discussed.

June 1865.

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ASTRONOMICAL GEOLOGY.

SECTION I.

AS TO THE PRESENT CONDITION OF THE EARTH'S CRUST, AND THE OPERATIONS WHICH ARE SUPPOSED TO HAVE PRODUCED IT.

Evidences of the present dry land having been covered with water in former times—the submergence of some parts of the earth's surface and the emergence of others are still in progress—the prevailing theory concerning the operations whereby those effects are produced—some objections specified.

THAT a great portion, if not all, of the present dry land has been covered with water, in times more or less remote, cannot be doubted. The existence of marine and fresh-water fossils in vast abundance, at different heights above the sea level in all parts of the world, can only be explained upon the supposition that their deposition occurred while the waters covered the localities in which they are now found. The condition of a considerable part of the earth's "crust" also points to the same conclusion. It seems impossible to imagine, for instance, that the stratified state of nearly all the soft, and of many of the hard kinds of rock, was produced otherwise than by the action of water; while "raised sea beaches," now far distant from any sea margin, and "ripple marks," and the foot

prints of amphibious animals, discovered in hardened rocks remote from sea, river, or lake, are plain indications of water having prevailed during a long period, in the neighbourhood of the sites where those tokens exist. Evidence to the same effect is everywhere traceable in the different forms and dimensions of hills and valleys—in the denudation which mountainous and many less elevated regions have manifestly undergone—and in the various features of every hilly district, including "bluffs" or "headlands," "cliffs" and "river terraces."

While from such appearances it seems clear that aqueous operations have occurred in localities now situate at various altitudes above the sea, and where neither river nor lake now exist, it is to be inferred from others that the sea and land have undergone very considerable changes of position relatively with each other. For instance, we are informed by writers of authority, that in the valley of the Jordan there are manifest signs of that remarkable depression in the earth's surface having been occupied by water, and of its having been in direct communication with the Red Sea in pre-historic times. From local indications, which are confirmatory of an early tradition to the same effect, there is reason to believe that the Black Sea was once entirely separated from the Mediterranean by an intervening tract of land, and that the Crimea, which is now a peninsula, once existed as

an island, in consequence of the water in the neighbourhood being much deeper than it now is. And in fact it can hardly be doubted that the features which characterize every sea coast, bear witness to the past occurrence of such "changes of level," and that evidence of their having taken place is to be met with in every part of the world.

It is known that, in the present day, the sea is gradually encroaching upon and submerging the dry land in many parts of the world. On the other hand, many coasts appear to be slowly rising higher above the sea level, or, in other words, the ocean seems to be receding from them.

Hence there is reason to believe that certain operations have been during long ages, and still are in progress, whereby some portions of the ocean bed slowly attain the condition of dry land and, on the contrary, some parts of the continents and islands of the world very gradually become permanently submerged.

It appears to be a prevailing opinion among geologists, that such changes in the condition of the earth's surface are being produced by volcanic agency; that while some portions of the globe's "crust" undergo a process of very gradual "upheaval," by means of volcanic forces existing within the earth, other portions sink or collapse and become submerged, in consequence of the withdrawal of those forces from be-

neath them, or of some other operation produced by that kind of agency.

The theory seems, in fact, to amount to this, namely, that the globe's surface is in some parts expanded or dilated by means of subterranean forces, which are so vast in degree, and so unequal as regards their local application, that all the irregularities, constituting the innumerable mountain and hilly ranges of the dry land, with its undulations and plains and valleys, are thereby produced; while other subterranean operations, arising out of the same igneous condition of the interior of the earth, cause the surface so to sink and collapse, that the cavities and depressions which are occupied by sea and ocean are thereby occasioned.

That heat exists within the earth in a very considerable degree, is manifested by the numerous volcanoes in a state of activity in different parts of the world, and by hot springs and other indications; and that it has performed a most important part in our planet's physical history, during past ages, is evident from innumerable extinct volcanoes, as well as from the igneous character of the materials forming the granites and other descriptions of rock.

Numerous objections present themselves, however, to the supposition that the structural and superficial irregularities of the globe's "crust" were produced by the operations referred to, *since* the "crust" itself

attained a condition of rigidity, and *since* the aqueous rocks were formed.

The following may be mentioned as some of those objections:—

(1) In inland localities, now far removed from sea, river, or lake, there can be unmistakably traced the water boundaries of ancient times, which present no indications whatever of their having been subjected to any violent disturbing force since the water disappeared from their neighbourhood. When, for instance, such water margins are found to surround extensive valleys at considerable heights, without any deviation from a horizontal position, it is impossible to imagine them to have been raised to their present altitude by an immense force, applied with such absolute equability from below, that not a sign can be detected of their having been violently disturbed, or of their horizontality having been in any manner affected.

(2) Extensive tracts of deeply undulating country are often found to be constituted of successive strata of aqueous rocks, which, with the earlier rocks below them, are said to have been subjected to this upheaving process. The strata are traceable over great distances, and they vary in a very considerable degree as regards the horizontality of their different parts; yet, when sections of them are exposed to view, they reveal no sign of disturbance *inter se*, and the material

of which each stratum is composed retains its original compactness entire. Now it is inconceivable that rocks consisting of hard and inelastic material, such as chalk or Portland stone for instance, and being some hundreds of feet above the sea level, can have been upraised into mounds and hills of all forms and dimensions, without being rent asunder in numerous places, or without having huge wedge-shaped gaps formed in their upper portions, or without displaying other palpable tokens of the force which had upraised them. Nor can it be supposed that layers of loose, brittle, or yielding materials, like shale or sand, would retain their relative positions, or fail to be intermixed and jumbled together, had they been subjected to such immense pressure from beneath as to have been raised to their present height above the sea level by that means.

(3) As the aqueous rocks are found to constitute the upper portion of the dry land in all those parts of the world with which we are acquainted, this theory, concerning the "upheaval" of the earth's crust since those rocks were formed, of necessity applies to the entire continents as well as to the numerous islands of the world. But the supposition that such vast areas are subjected to those subterranean volcanic forces, which are said to be always in operation, seems to be utterly irreconcilable with the fact that palpable signs of their existence are so seldom felt!

(4) Undulatory and precipitous irregularities of

surface are characteristics of every country; some of them taking the form of rugged mountain masses and some of immense hills, while others are graduated into mere gentle slopes. Hence it is to be implied that the forces producing those inequalities have been variable in degree, and casual as regards locality. It is in situations possessing some of those characteristics, that many ancient cities and towns are located; and, in many parts of Europe, it is in places at or near to which public edifices and human habitations are known to have existed for centuries, that changes in the level of the sea relatively with the dry land are said to be taking place at the present day. Now, seeing how necessary it is to the existence of a building that its horizontal position be preserved, and how great an effect upon its stability any disturbance of the soil in which its foundations are embedded is calculated to produce, it is as remarkable, on the one hand, that the numerous structures that have been very long in existence upon many an ancient site, should bear no sign of unsettlement or disturbance (supposing these irresistible forces to have been, however gradually, applied to the earth beneath them), as it is, on the other hand, that the sites on which those structures remain should have escaped the application of those forces, supposing them to have been, and still to be, in operation in the immediate neighbourhood. The importance of these considerations, as bearing upon this part of

the subject, is in no degree diminished when it is borne in mind how terribly destructive are the effects produced by those subterranean forces, when they do make themselves palpable, as they unfortunately often do, in the form of earthquakes of greater or less severity.

Such are a few of the many difficulties which stand in the way of the prevailing theory, with regard to the mode by which the aqueous rocks have attained their elevated position. That those difficulties have been but little noticed, may be owing to the circumstance that the attention of practical and scientific geologists has been directed to the details of the science, with the view of determining the relative places in the chronology of the earth's "crust" to be assigned to the different strata, of which it is in great part composed, rather than to the causes whereby the main features of geological phenomena have been produced. It may be, in fact, that the theory in question is indebted for its favourable reception among scientific men, not so much to its feasibility, as to the absence of satisfactory explanations of the appearances from which it is deduced.

SECTION II.

FURTHER CONSIDERATION OF THE EARTH'S PRESENT PHYSICAL CONDITION, AND OF SOME OF THE CAUSES WHICH HAVE PROBABLY CONDUCED TO IT.

The earth's oblate-spheroidal form—the "igneous" origin of the lower portions of its "crust"—its shape is due to the matter constituting it having been subjected to rotary motion while in a ductile state—the structural and superficial irregularities of its "crust" are due to the process of refrigeration through which it has passed—while the earth's surface remained in an intensely heated state, the aqueous vapours which surrounded it could not condense upon it—therefore seas, &c., were subsequently formed.

In the course of the following pages an attempt will be made to show that the formation of the dry land, and therefore the elevation of the aqueous rocks above the sea level, is an effect produced in consequence of certain astronomical causes which are ever in operation. Preparatory, however, to a discussion upon that part of the subject, a few remarks will be ventured upon respecting some of the circumstances which are known to have conduced, or which have probably conduced, to the present physical condition of the globe.

(1) We are informed by astronomers that the earth is of an oblate-spheroidal form, and that it has

at the equator a diameter longer than that at the poles, to the extent of about twenty-six miles; or a difference in radius of thirteen miles. Excluding from present consideration the "volcanic" and "metamorphic" rocks, as well as those of the "aqueous" class which occupy the most recent place in the earth's chronology, and also excluding therefrom the water, which, as compared with the whole earth, may be described as forming but a mere film upon its surface, it cannot be imagined of the vast mass of which the globe consists, otherwise than that it took this shape or form while it was in a semi-liquid, yielding, or elastic condition, such as would permit it to obey, to some extent, the centrifugal impulse caused by the earth's rotation on its axis, and having at the same time, in virtue of the power of gravitation, or of centripetal force, or of some property it possessed, or influence to which it was exposed, such a compactness and cohesiveness as to prevent its dispersion, and finally to restrain it from assuming a greater equatorial expansion than it now possesses.

(2) The texture and general characteristics of the material of which the nethermost portion of the earth's "crust" entirely consists, namely, the granite of different kinds, unmistakably indicate that it was in a state of fusion before it attained its present indurated condition. All the other descriptions of rock also, excepting those of the fossiliferous

or aqueous class, are said to bear evidence of their having been subjected to an intense degree of heat.

And that heat has been the principal agent in many of the operations which occurred during an early period of our globe's history, is manifest from the numberless extinct volcanoes which exist in various parts of the world. And it is to be inferred, from the numerous volcanoes now in a state of activity, as well as from hot springs and other evidences, that the interior of the globe has retained a very considerable degree of heat even to the present day.

From such circumstances, the inference seems to be inevitable, that the materials of which the globe consisted, in an early stage of its history, were in an intensely heated or fused, as well as a yielding or elastic condition, and that it was while they were in that state that the earth's spheroidal form was acquired. And further, that it was not until those materials had become somewhat compact and rigid, in consequence of the refrigerating influences to which they were exposed, that the daily rotation of the earth upon its axis ceased to have any effect upon its shape, and that the form it is now found to possess was finally attained.

(3) The refrigeration of that vast mass of material *must have proceeded from the surface inwards*, and it may be conjectured that, while the outer portion of the globe was, by means of that process, assuming a compact and solidified state, the gaseous vapours

which continued to be generated in enormous quantities, were thereby restrained from freely escaping at every point of the surface, as they had done previously to the congealing process setting in. Their accumulation would therefore occur in different places beneath that outer portion or "crust" of the globe which was thus slowly attaining a state of solidity. By reason of the prevailing heat, those accumulating gases would acquire an irresistible expansive force, whereby the parts of the solidifying but yet elastic "crust" which were most capable of yielding, would become raised into innumerable protuberances of various heights and dimensions, some of which would ultimately give way to the pressure from within, and become "vents," through which the gases would make their escape.

The suggestion occurs, on the other hand, that the partial exhaustion of the internal fires would occasion portions of the globe's surface to become sunken and collapsed, whereby a still greater degree of irregularity would be imparted to the localities where such operations were in progress.

Supposing, then, the materials of which the earth was composed to have been in a fused or molten state, and to have passed through the process of gradual refrigeration described, its "crust" must have become subjected to the most powerful and unequally applied upheaving force, *while it was attaining a state of rigidity*

and compactness, and long before it had acquired a completely indurated condition; and all the irregularity which constitutes mountain, hill, valley, and plain, must have been thereby produced upon its surface.

(4) It may certainly be assumed, that while the globe was in the fused or intensely heated condition described, it did not bear moisture in a liquid form upon its surface, and that neither ocean, lake, nor river were in existence. It is reasonable to suppose, however, that as its "crust" gradually progressed towards a settled condition of rigidity, its surface became, part by part, sufficiently cool to allow the aqueous vapours, which probably surrounded it in enormous quantities, to condense on the mountainous projections which had been raised upon it, and that the water thus formed found its way by various channels into less elevated districts, whose surface probably was at first in too intensely heated a condition to permit it to remain unvaporised.

The very great difference between the climates of the globe in different latitudes, in our own times, seems to warrant the conjecture, that its temperature varied to at least as great an extent during the early stages of its history under consideration, and that some regions long before others were in a condition fitted for the deposition and accumulation of the watery element. When, however, its formation in different regions had once begun, and numerous areas of vast

extent had become covered with the continuously increasing flood, its gradual extension to all the parts of the globe which it was destined ultimately to occupy, would necessarily follow, whatever might have been the condition of the globe's surface in those other regions over which it finally prevailed.

Thus, probably, were the seas and oceans with which the globe is encircled, gradually formed in the course of a very lengthened period during which other operations of vast magnitude, and of a chemical as well as a mechanical character, were also conducing to the physical condition which it was intended our earth should ultimately attain.

SECTION III.

CONCERNING THE WATER UPON THE GLOBE.

As to the scientific explanations respecting the supposed average depth of the ocean in all parts of the world—circumstances which seem to be in conflict with those explanations—importance of the question as bearing upon the formation of the aqueous rocks—the spherical form was probably attained by the globe under circumstances very different from those under which water became deposited upon its surface—it may, therefore, be doubted whether the earth's watery envelope corresponds, in exterior shape, with the general form of the globe—that the ocean is not of an average depth all over the world, is to be deduced from the astronomical explanations of the tides—those explanations considered—necessary inference therefrom—as to the mode in which the daily tidal alternations occur.

WHATEVER may have been the nature of the operations to which the globe was subjected prior to the formation of the aqueous rocks, it can hardly be doubted that the vast mass of matter of which the earth is composed had attained a condition of rigidity, and had finally assumed the shape it now possesses, before it was possible for the immense bodies of water with which the largest proportion of the globe is now covered, to be deposited and retained upon its surface.

As it is manifest that the deposition of the "aqueous" rocks occurred in some way through the action of water, it may assist in the enquiry respecting their formation, upon which it is proposed to enter, to consider some of the circumstances which regulate the condition of sea and ocean, and result in the vast operations which are ever in progress through the instrumentality of those enormous collections of water.

We are informed by astronomers, that the immense body of water which encircles our globe and comprises the great seas and oceans of the world, is of an *average uniform depth;* in other words, that its exterior surface exactly conforms with the general shape of the globe, upon which it forms a kind of liquid envelope or covering, filling all the hollows, and concealing all the inequalities which exist in the surface of the solid earth beneath. And scientific explanations respecting the power of gravity exercised by the globe over the water on its surface, and as to the effect produced upon it by the centrifugal force occasioned by the earth's diurnal rotation, are given to us by the same authorities to show that an unequal collection of water is prevented, either in the direction of the poles of the earth on the one hand, or of the equator on the other.

There are circumstances, however, which seem to be in conflict with such explanations, and which are suggestive of considerable doubt, whether the waters

forming the oceans of the world do, in fact, exactly correspond in exterior shape with the form of the earth, and whether they are not collected in greater quantity in some regions than in others.

This question, concerning the uniformity of the depth of the waters surrounding the globe, is of great importance in the present enquiry, for if it can be shown that their exterior surface does not exactly conform with the shape of the earth, and that their general depth (*i.e.* irrespective of the inequalities in the earth's surface beneath them) is much greater in some regions than in others, it seems possible to account for the formation of the aqueous rocks upon a much more reasonable hypothesis than that which now prevails upon the subject.

If the physical laws by which matter is now regulated were in operation during the period of the earth's formation, and if the material of which the solid part of our globe is composed was in a fused, partially fused, or pliable condition, while resolving into a condition of equilibrium and attaining its present oblate-spheroidal shape, the circumstances under which the power or influence of those laws conduced to that form or shape, must have been very different from those under which they were exercised upon the water which came to be deposited on the earth after it had settled into a condition of rigidity. On the one hand, we have to imagine a vast globe of com-

pact cohesive matter, of a density much greater than that of water, revolving on an axis by an independent motion of it own, and thereby attaining, as an entire mass, a certain determinate shape; and on the other, a volatile fluid which, having been deposited on a rotating solid globe of immense proportions, forms upon that globe a mere partial, filmy covering, and partakes of its rotary motion. The circumstances of the two cases being so different, it seems impossible to suppose otherwise than that there must be a difference in the result, and that the shape or form of the great collection of water enveloping the earth, diverges to a considerable extent from that of the earth itself, and that the water is accumulated in greater depth or quantity in some parts than in others, in consequence of the great velocity at which it is carried round on the surface of the globe.

But a more cogent reason than that already suggested in support of the conjecture, that *the waters of the ocean do not exactly correspond with the general form of the globe, and are not of an average or general uniform depth*, seems to be deducible from the explanations given by astronomers concerning the influence or attractive power of the sun and moon, by which the daily alternations of tide are produced.

We are informed, that the tides occur in consequence of the parts of the ocean most directly exposed to the solar and lunar influences, being raised

or heaped up into "waves," which "follow" the attracting luminaries in their apparent diurnal courses.

The greatest amount of these influences is said to be exercised upon the ocean when the moon is in "conjunction," or "opposition," namely, when the earth, the moon, and the sun, are so relatively situate as to be all in one straight line, the waters being then accumulated or heaped up to their greatest height, and the well-known result of "spring tide" being then manifest. The minimum effect, or "neap tide," is said to happen when the moon is "in quadrature," that is, when it is so situate that two straight lines, namely, one projected from its centre, and the other projected from the centre of the sun, would form a right angle at their junction in the earth's centre.

It appears, therefore, that "spring tides" are the effect produced by the sun and moon conjointly, and that "neap tides" are attributable to the separate effect of the moon's influence (which is more powerfully felt than that of the sun, in consequence of the nearer proximity of the moon) upon the waters at one part of the globe, when that effect is partially separated from, or counteracted by, the effect of the sun's influence upon the waters at another part.

Another, though an indirect result attributed to the attraction of the sun and moon, is the simultaneous production, on the side of the globe opposite to that directly exposed to the influence of the two lumi-

naries, of effects precisely similar to those just described. The astronomical explanation of the causes from which those further effects are said to arise, will not, however, be attempted, it being only necessary for the present purpose to consider generally the manner in which the waters surrounding the earth are said to be affected by the attractive power of the sun and moon.

We are led, by the explanations first referred to, to suppose that the daily tidal changes observable in many rivers and on sea shores are occasioned by the *oscillation* of a lunar, and also of a solar, "wave" in each hemisphere, and the apparent ebb and flow of the water, with which every person is so familiar, seems to corroborate the supposition. A little consideration, however, of the causes which, according to the teaching of astronomy, contribute to the alternations of the tides, seems to lead to a very different conclusion as to the manner in which they are produced.

Now, as the tidal effects are attributable to the attractive influence or power exercised by the sun and moon upon the waters, and as the degree or amount of that influence or power varies according to the distance which intervenes between its source and the object affected, it follows (our planet being spherical) that the force or power of gravitation exerted upon the waters at that part of the globe over which the attracting luminary is directly vertical (or to which it is nearest), is greater than that which is exerted

upon them at other parts of the globe; and that the amount of force or gravitation exercised, diminishes in some ratio which accords with that increase of distance from the luminary, which is occasioned by the earth's sphericity.

Instead, therefore, of the waters being drawn or heaped up into an oscillating "wave," in consequence of the sun or moon's position relatively with the earth, it would seem that the effect of the attractive power of either must necessarily be, *directly*, the production of a vast cone-shaped volume of water extending over the entire hemisphere (excepting where interfered with by continents and islands), having its apex or deepest part immediately under the attracting luminary, and gradually diminishing in depth and volume in all directions surrounding that point; and, *indirectly* (according to the astronomical explanations concerning the effect of the solar and lunar attraction upon the ocean), the accumulation of a similar body of water in the opposite hemisphere.

But, whether the waters of the ocean are raised by that attractive power into the shape of "waves," or into volumes or masses of another form, these results seem to be certainly deducible from the explanations concerning them which astronomy affords, namely:—(1st) That they are accumulated into volumes or masses which, as regards depth and quantity, are greater in some regions than in others.

(2nd) That those volumes or masses retain, notwithstanding the earth's rotation on its axis, *positions which are permanent relatively with the luminaries producing them*, and which, therefore, do not vary cotemporaneously with the alternations, called tides, observable in rivers and on sea-shores;—and, therefore, (3rd) that the daily tidal alternations occur, not in consequence of an actual oscillation or ebb and flow of the waters, but by reason of the coasts and shores being brought, by the diurnal rotation of the solid globe, through those portions of the water surrounding the globe, which ever continue to hold their positions relatively with the sun and moon, and independently of the earth's motion, and which are of an unequal though regularly graduated depth.

If those general averments are true, it seems necessarily to follow, that the immense collection of water with which the earth is nearly encircled, does not exactly coincide, superficially, with the shape of our planet, and that it does not entirely participate in the daily rotary motion of the solid globe beneath, or rather within it; and also that, it permanently possesses a much greater depth or volume in some regions, than in others.

SECTION IV.

THE ASTRONOMICAL EXPLANATIONS OF THE TIDES CONSIDERED.

The manner in which the attracting power of the sun and moon upon the ocean is said to overcome that of the earth to some extent—solar and lunar masses or volumes of water are thereby permanently produced—their depth is not uniform, but is graduated from certain apices or deepest parts, which are always maintained in situations lying in or near to the plane of the ecliptic, notwithstanding the various motions of the solid earth—the manner in which the daily tidal alternations are hence occasioned.

Not only is it to be deduced from the circumstances on which the tidal alternations are said to depend, that the waters enveloping the earth are accumulated in greater depth or volume in some regions than in others, and that the daily tides are occasioned otherwise than by an actual oscillation or "flow" and "reflow" of the ocean, but other important inferences are also to be drawn therefrom concerning those wonderful geological events of which the crust of the earth exhibits such abundant traces.—An analysis of those circumstances will therefore be now attempted in somewhat greater detail, even though some of the remarks contained in the previous pages may have to be repeated.

From the explanations given in works which treat upon the subject, it is to be inferred, that the earth's gravitating or attracting power upon the ocean is in some measure overcome by that of the sun and moon, and that the solar and lunar influence not only prevents the waters which surround the globe from assuming a shape corresponding exactly with that of the earth itself, but also prevents them, in the measure in which that power or influence is exerted upon them, from participating in, or being carried round with the diurnal rotation of the globe.

In consequence of our planet having a spherical form, the place upon its surface between which and the sun or moon there intervenes the least distance, is, of course, that over which the luminary is immediately vertical. And as the attracting power diminishes proportionately with the increase of distance intervening between its source and the object affected, it follows that the solar and lunar influence must cause the waters of the ocean to be so drawn or accumulated together, that they possess a greater depth at the part over which the attracting luminary is directly vertical than elsewhere, and that their depth (so far as the accumulation is occasioned by the sun or moon's attracting power) gradually diminishes in a ratio according with the increase of distance from that part or point.

A precisely similar "heaping up" or accumulation

of the water is said by astronomers to take place simultaneously in the hemisphere opposite to that over which the sun or moon happens to be. The scientific explanation of this occurrence is difficult to describe, and is unnecessary for the present purpose; but it may be not improperly expressed as the *indirect* effect of the solar or lunar influence upon the ocean.

Hence it appears, as regards the SUN's attractive power (considered separately from that of the moon), that it affects the ocean in such a manner as to cause the water in each hemisphere to be accumulated together, or "heaped up" into a condition of varied but regularly graduated depth, and so that (in respect only of that inequality of depth which is produced by the sun's attractive power) *its deepest parts always continue in an unvarying situation relatively with the sun*, notwithstanding the earth's daily revolution on its axis, and so that a straight line would pass through their respective apices and the sun's centre.

The moon exercises an attractive power similar in kind to that of the sun, but, owing to its nearer proximity to the earth, it produces a much greater effect upon the ocean, and consequently, a mass of water is accumulated together by it in each hemisphere, considerably exceeding in depth and quantity that produced by the other luminary.

Whether the whole mass, or only a portion of the

waters surrounding the globe, is thus affected by the attractive power of the sun and moon, matters not, so far as concerns the conclusion to be formed from a consideration of the manner in which that influence is exercised. It may, however, be convenient to deal with the question on the supposition that, in consequence of a part of the ocean being thus accumulated together, or held in a state of suspension, there exist in each hemisphere two vast masses or volumes of water, the one being produced by the moon's attractive power, and the other by that of the sun; the apex or deepest part of the volume of water raised by the sun's direct influence, and that of the corresponding volume in the opposite hemisphere, being always retained in the same situation relatively with the sun, and similarly the apex or deepest part of each of the two lunar volumes being always retained in the same situation relatively with the moon.

Although, then, these volumes of water are retained upon the globe by its gravitating or attracting power, yet they are not carried round, or materially affected by the daily rotation of the earth upon its axis, and their positions upon the globe throughout each day and month and year, only and altogether depend upon the relative situations which the earth, the moon, and the sun, bear towards each other.

As the greatest depth of the mass or volume of water accumulated by the sun's direct influence is

always situate at that part of the globe's surface over which the sun happens to be vertical, and as the corresponding mass or volume occupies a position diametrically opposite to it, it follows that the situation on the surface of the globe, of the deepest parts of these two solar masses of water must *always* be somewhere in or near to the part where the imaginary plane of the earth's orbit (usually spoken of as the plane of the ecliptic) happens to divide the globe.

And, similarly, the deepest parts of the two lunar volumes of water must be situate somewhere in or near to the part where the imaginary plane of the moon's orbit round the earth happens to divide the globe.

Now the plane of the moon's orbit is said to diverge from that of the earth round the sun to the extent of about five degrees only.

As, therefore, the two planes so very nearly coincide, it would appear, from what has been stated, that the deepest parts of the two lunar masses of water, and of the two solar, continue to retain (notwithstanding the earth's revolution on its axis) situations which always lie in or near to the plane of the ecliptic.

But that plane may be said to hold an absolutely fixed place in the heavens notwithstanding, and whatever may be the motions of the earth and its satellite.

It therefore follows that, by the daily rotation of

the solid globe on its axis, all the parts of its surface, including its sea coasts and channels, are made to undergo a continual change of position, relatively with those deepest parts of the solar and lunar volumes of water.

In or near to those parts of the globe's surface, however, through which this plane of the ecliptic is supposed to pass, the position of the deepest parts of the two lunar volumes of water must undergo frequent change, in consequence of the moon's monthly journey in her orbit. In every revolution she makes round the earth, she is once in "conjunction" with, and once in "opposition" to the sun. As the deepest parts of the two lunar volumes of water always correspond with the situation of the luminary in the zodiac, it follows that they become, at the two periods mentioned, added to or merged with the two solar volumes, producing the "spring tides," to which allusion has already been made. Immediately after either of those occurrences, the lunar volumes of water in each hemisphere begin to separate from the solar, and they continue their separating progress until the moon's arrival in "quadrature," when an interval of 90 degrees between the deepest parts of the solar and lunar volumes of water having been attained, the two lunar volumes begin to approach the solar, and continue their approach until a mergence together recurs at the

time of the moon's "conjunction" or "opposition," as the case may be. And thus it would seem that the production of "spring tides" is the effect of the united influences of the sun and moon upon the ocean; and that "neap tides" occur when, in consequence of the separation of the two luminaries by a distance of 90 degrees, their attractive power upon the ocean is least felt.

SECTION V.

CONSIDERATION OF THE TIDES CONTINUED.

The tidal effects of the solar and lunar influence upon the ocean, as manifested on the coasts and channels of the sea—flow of the tide—high water—ebbing tide—low water—semi-monthly variations—spring and neap tides—propositions into which the subject of the tides may be resolved.

It appears, then, from the manner in which the solar and lunar power is exercised upon the ocean, that the waters are so held in a permanent state of suspension that a greater depth is imparted to some parts of them than to others—the shallowest portions being situate at a distance of 90 degrees from the place upon the globe over which the sun or moon happens to be vertical, and the deepest parts being situate at that place and at the diametrically opposite part of the globe, those deepest parts being always somewhere near the plane of the ecliptic.

Now, the diurnal rotation and the other motions of the globe, cause the different parts of the surface of the solid earth, with its river banks and sea shores, to be continually undergoing a change of position relatively with that imaginary ecliptical plane, which, passing through the centres of the sun and earth, may be said to hold throughout all time an immoveable position in

the heavens; and, in order to ascertain the state of circumstances produced in consequence of the ocean being thus regulated by a power or influence exterior to itself, it may be convenient that the nature of such change of position should be traced.

And, first, it is obvious that, in consequence of the direction of the daily rotary motion being parallel with the equatorial plane, which diverges from the ecliptical plane to the extent of about 23½ degrees, that motion must cause all parts of the solid earth's surface continually either to approach towards, or to recede from, the plane of the ecliptic *in an oblique direction.*

And, supposing a vast mass of the waters to be retained by the solar and lunar attractive power in such a manner that it is not carried round by the earth's daily motion, but is so held in suspension that its depth gradually increases towards certain parts lying near the ecliptical plane, then it is clear that, when any sea coast is, by that motion of the earth, being carried round towards a part of the ecliptic where one of those points of greatest depth exists, all the indications of a *rising tide* must be apparent, and all those rivers and channels in its neighbourhood, which happen to be accessible to the sea, must become partially immersed in, and occupied by, the deepening flood. On the same sea coast arriving *as near to that part of the ecliptical plane as it can reach*, it has been brought into

the deepest portion of water accessible to it; and the phenomenon of "high water" is the result; its continued progress being afterwards in the direction in which the waters decrease in depth, produces the effect of ebbing tide, and a distance of 90 degrees from the same part of the ecliptic being attained, "low water" takes place, in consequence of the shallowest portion of water being reached; and the earth's continued motion then brings the coast again within 90 degrees of the opposite part of the same plane, its approach towards which causes the repetition of an apparently flowing tide; and a recurrence of the same events follows as before.

The effect thus produced, in consequence of the sun and moon both exercising such an influence, becomes complicated by the monthly revolution of the moon in its orbit. It would seem that, when that luminary travels from its position of conjunction or opposition, the waters of the ocean being affected by the change, must become drawn out of the spherical shape at two points *in each hemisphere*, one of them being at that part of our planet's surface over which the sun is vertical, and the other where the moon holds a similar position, producing altogether FOUR apices or points of greater depth. The position of these four points being dependent on the relative situations of the earth, sun, and moon, they are sometimes separated from each other by equal intervals of 90 degrees, as at the time of

neap tides; after which event the lunar volume in each hemisphere begins to approach the solar, and continues its approach until the two are again merged together as at the time of spring tides.

But if such are the effects occasioned in consequence of the attractive power of the sun and of the moon being exercised separately, then it would seem that, excepting only when the moon happens to be in "conjunction" or "opposition," there must be manifested daily four tidal alternations, namely, the two principal tides produced by the moon's attractive power, being those which are actually observed, and which vary in the times of their occurrence, and in the degree in which they are developed, correspondingly with the moon's progress in her orbit, and the two solar tides occurring with greater regularity than the others, by reason of the greater slowness of the change in the circumstances on which they depend.

Now, although it is an occurrence not commonly observed, yet it is a fact, that *four daily tides* do sometimes happen in places which are favourable for their manifestation, as at Poole, in Dorset, and probably on many other coasts.

According to astronomical explanations on the subject, however, it appears that, by reason of the distance of the sun from the earth being immensely greater than that of the moon, the solar influence, as exercised upon the ocean, is very much less powerful in degree

than that of the other luminary; and the separate tidal manifestation thence arising is no doubt, therefore, comparatively inconspicuous and insignificant; and it is probable that any effect really resulting from it is supposed by ordinary observers, those, for instance, who are stationed at the entrances of harbours, or who are engaged in sea-shore employments, to be only a deviation from the usual ebb and flow of the water, such as very frequently occurs in consequence, as it is thought by them, of the wind blowing with greater violence than usual from some particular quarter, or of some other supposed exceptional circumstances.

The foregoing remarks, concerning the manner in which the ocean is affected by the attractive power of the sun and moon, may be briefly summed up in the following propositions :—

(1) The waters surrounding the globe do not, superficially, exactly coincide with its form ; but,

(2) They may be regarded as a partial envelope or covering to the solid globe, the depth or thickness of whose several parts varies according to the position which those parts hold relatively with the sun and moon.

(3) They are affected by the solar and lunar attractive power in such a manner that their depth is greater in the parts over which the sun and moon are vertical, and in the parts diametrically opposite thereto, than elsewhere, and is diminishingly graduated in all directions surrounding those deepest parts.

(4) Their condition, so far as it is dependent on the solar and lunar influence, is permanently maintained, so that the positions of their several parts continue unaltered relatively with the sun and moon, notwithstanding the earth's daily rotation on its axis; that is to say, to the extent (quite, or nearly) to which the waters are affected by the sun and moon's power, they are not carried round by, or in consequence of, the daily rotation of the globe.

(5) Those points or parts of greatest depth always hold positions which are in or very near to the plane of the ecliptic.

(6) The daily tidal phenomena are produced in consequence of the sea coasts and channels being brought, by the daily rotary motion of the globe, into successive positions relatively with the different parts of the ocean so suspended in a condition of unequal depth, and *not* by an actual advance and recession of the waters to and from the coast or place where they are observable.

SECTION VI.

CONCERNING SOME OF THE EFFECTS RESULTING FROM THAT MOTION OF THE EARTH WHICH OCCASIONS THE "PRECESSION OF THE EQUINOXES."

Although periodical variations in the condition of the ocean are caused by means of the earth's revolution in its orbit, it is not likely that any important geological effects are thereby produced—the effect of "nutation" not considered at present—how the "precession of the equinoxes" is occasioned—an alteration of climate in all parts of the world, and an alteration in the relative levels of the sea and dry land are produced by the same means.

If the ocean is always retained in such a condition that it ever has a greater depth or volume in certain parts lying near the ecliptical plane than elsewhere, and that the daily rotation of the earth upon its axis occasions the alternations of the tides, by causing the sea shores and the channels accessible to the sea continually to undergo a change of position relatively with that plane, then it would seem to follow, that phenomena of a similar character, but occupying proportionately more lengthened periods in their development, must be produced in consequence of the other motions of the earth.

For the purpose of considering what alteration in

the condition of the ocean, if any, is caused in consequence of the motion of the globe in its orbit, resort must be had, as in the case of the daily tides, to astronomical explanations.

It is to be again observed then, that the plane of the equator, parallel with which is the direction of the earth's daily rotation on its axis, diverges from that of the ecliptic in which the earth pursues its yearly journey. This well known circumstance, usually spoken of as the "obliquity of the ecliptic," may be otherwise explained by stating, that the divergence of the earth's axis from a position of parallelism with that straight line which lies between the poles of the ecliptic (and which therefore may be called the axis of the ecliptic), causes a like measure of divergence between the planes of the equator and ecliptic; and that, excepting a minute alteration to be shortly alluded to, the poles of the earth continue to point to the same parts of the heavens throughout the planet's annual revolution round the sun. If the earth's axis were parallel with that of the ecliptic, the different parts of the earth's surface would not undergo a change of position relatively with the sun other than that produced by the earth's daily rotation on its axis, and the variations in the seasons which we experience would not occur; but, in consequence of this "obliquity" or divergence, it follows that by means of the earth's motion through space,

all parts of its surface undergo such a succession of changes of position relatively with the sun (and also with the ecliptical plane, but not involving any angular alteration relatively therewith), as results in the yearly recurrence, in their regular order, of spring, summer, autumn, and winter.

As, however, the condition of the ocean, as dependent on the position of the sun and moon, is not altered in consequence of the progress of the earth in its orbit, the effect likely to result from that motion is, that the masses or volumes of water produced by the sun's influence are made to revolve once round the globe in the course of each year (their apices or deepest parts being always in the plane of the ecliptic), in the same manner as the masses or volumes of water produced by the moon's influence are made to perform their monthly revolution. Hence it is to be expected that some variation in the tidal effects would become manifest in the course of the year.

Now, it is observed by persons stationed at some harbours' entrances and pier heads, that in the course of every year there does occur, at two corresponding periods, a flow of water of greater height than any that happens at intermediate times. It would seem, therefore, that the effects which actually occur, although not very conspicuous as regards their amount, coincide with those which are deducible from astronomical theory. Being, however, of frequent and

regular recurrence, they do not admit of the supposition that the condition of the ocean bed is permanently affected by them, or that any important geological results are produced by them; and, therefore, they need no further consideration at this stage of the inquiry.

The motion of our globe through space is subjected to certain disturbing influences whereby other motions are apparently engendered, the most important of which are manifested in the "nutation of the earth's axis" and in the "precession of the equinoxes."

No very conspicuous change in the level of the sea relatively with the dry land is observable within the period of any one occurrence of the phenomenon of "nutation." Nevertheless, it seems probable, that the motion which produces it occasions some alteration in the ocean's condition, especially in causing a variation in the direction of some of the great oceanic currents. Whatever may be its effects in some respects, however, its continual recurrence at comparatively short intervals, renders it unlikely that any permanently abiding geological results proceed from it, and, therefore, no discussion as to any alteration of circumstances to which it may give rise will be here entered upon.

The most important motion of the earth which bears upon the inquiry in hand, is that which occasions the "precession of the equinoxes." As previously

explained, it is in consequence of the earth's axis being otherwise than parallel with the axis of the ecliptic, and of each pole of the earth's axis, respectively, being directed exactly to the same point in the heavens throughout every revolution of the globe in its orbit (excepting the alteration which occasions "nutation" and "precession"), that the annual variations in the seasons experienced in all parts of the world arise. The amount of the present angular divergence of the earth's axis from a position of parallelism with that of the ecliptic, namely 23° 28′, is of course the measure of angular separation between the equatorial and ecliptical planes.

The "precession of the equinoxes" is said to consist of a regression of the equinoctial points along the line of the ecliptic, and to be occasioned in consequence of a kind of oscillatory or conical motion of the earth, whereby each of its poles is made to describe a circle or other figure in the heavens at so slow a rate that a period of about twenty-six thousand years is consumed while only one such revolution is performed.

In some works upon the subject, it appears to be affirmed that the poles of the earth, while performing this slow revolution, ever continue to retain the same angular divergence from the poles of the ecliptic, and it seems to have been theoretically concluded that the plane of the circle thus represented in the heavens by

either pole of the earth must be paralled with the plane of the ecliptic, and that the measure of divergence between the ecliptical and equatorial planes does not vary.

Now, for this occasion, regarding the axis of the ecliptic as being immoveably fixed in the centre of the earth's orbit, and of course at right angles with the ecliptical plane, it appears to be absolutely impossible, if the direction of the earth's axis in space becomes thus altered, that the same measure of divergence from a position of parallelism can be constantly maintained between the two planes.

If, for instance, in consequence of the conical motion of the axis of the earth, there is thus described by each pole a circle whose semi-diameter is measured by an angle at the earth's centre of 23° 28′, it certainly follows, that when half that circle is completed, each pole must have altered its position in space to the extent of twice that measure, namely to the extent of the diameter of that subordinate circle. The earth's axis in relation to the pole of the ecliptic, and the plane of the equator in relation to the plane of the ecliptic, must thus have undergone that degree of alteration, and hence it must have happened, that in the course of the period occupied in the performance of that half revolution of each pole of the earth (namely in about thirteen thousand years, or revolutions of the earth in its orbit), the equatorial plane

must have gradually approached the ecliptical until it coincided with it, and then have as gradually separated from it, until it had attained the same angular divergence of 23° 28′. The probability seems to be that, instead of describing a circle in the heavens, each pole of the earth describes an ellipse. The result produced must nearly resemble that which would occur if the earth possessed a direct oscillatory motion upon an axis passing through its centre at right angles with the axis of daily rotation.

In such an alteration of position relatively with the surrounding heavens, and with the ecliptical plane, all parts of the solid earth's surface must of course have participated, and every region of the globe must thus have experienced very considerable, though very gradual changes of climatal condition. And, supposing that the waters which envelope the earth are affected by the solar and lunar influences, in the manner previously described, the surface of the sea and that of the dry land, each relatively with the other, must also have undergone changes of position of a most decided character.

One of the most palpable effects caused by the rotation of the earth upon its axis, is the continual change of position which is undergone, during the time occupied by a single revolution, by the different parts of the earth's surface relatively with the sun and fixed stars. The slow motion of the earth under

consideration must of necessity produce a change of a similar character, the motion being of course in a different direction. Although it is so slow and gradual in its development as only to be capable of detection after repeated scientific observation, yet it is as certain that it must cause the different parts of the earth's surface to change their situation in regard to the surrounding heavens (or with the plane of the ecliptic which amounts to the same thing), as that such an effect is produced by the earth's daily rotation on its axis.

On the one hand, therefore, stands the hypothesis deducible from the astronomical explanations of the tides, that the vast collections of water upon the globe are, by the solar and lunar attractive power, retained in such an ever abiding condition, (1) that they permanently possess a shape which does not exactly coincide with the shape of the globe itself, and (2) that their depth is diminishingly graduated in all directions surrounding certain parts of them which are ever retained in situations in or near the plane of the ecliptic, notwithstanding the various motions of the earth, including the motion which occasions the "precession of the equinoxes."

On the other hand is the fact, that relatively with that plane, and therefore with the deepest and other portions of the earth's watery envelope, the different parts of the globe's surface, including continents, islands,

coasts, channels, and sea beds, are slowly and gradually undergoing a change of position.

From these premises it is certainly to be concluded, that in consequence of this oscillatory or conical motion of the earth, "changes of level" are occasioned between the land and the sea, each relatively with other, in such a manner that every coast and channel of the sea gradually either becomes more deeply immersed in, or is made to emerge further out of, the water in its neighbourhood.

SECTION VII.

AS TO WHETHER THE PREVIOUSLY CONSIDERED CIRCUMSTANCES ARE SUFFICIENT TO ACCOUNT FOR THE PAST "CHANGES OF LEVEL" INDICATED BY THE EARTH'S CRUST.

The inequality of the ocean's depth, as manifested in the daily tides, is not sufficient to account for those "changes of level"—the daily tides show how the ocean is affected by the influence of the sun and moon, but they do not indicate the total difference in the effects resulting from that influence at different parts of the globe—the fact that some change of level is produced by the means described, constitutes a strong *primâ facie* reason for concluding that the changes revealed by geology were thus occasioned—other circumstances affecting the question strengthen that conclusion—difference between the length of the earth's diameter at the equator and at the poles—the effect upon the ocean of the earth's daily rotation on its axis, and of its motion in its orbit—the irregular configuration of the earth's surface—the evidence afforded by the aqueous rocks—their structure, fossil contents, and superficial configuration—the conclusion deducible from the various circumstances enumerated.

It is, then, certainly demonstrable from astronomical explanations (1st) that, notwithstanding the various motions of the globe, the waters surrounding it are always retained in such a condition that they are deeper in certain places lying in or near the ecliptical plane than elsewhere, and that their depth

gradually diminishes in all directions surrounding those deepest parts to the distance of 90 degrees therefrom; and (2nd) that the daily tidal manifestations occur in consequence of that inequality of depth, and of the direction of the globe's daily rotary motion being otherwise than parallel with the ecliptical plane.

It is further as certainly demonstrable that the change in the position of the earth's axis, which occasions the "precession of the equinoxes," causes the level of the sea, and that of the dry land, to become altered, the one relatively with the other; and that such alteration of level is precisely of the same kind as that of which the daily tidal alternations consist, but is so slowly produced as only to become conspicuous after very lengthened periods have elapsed.

And it remains to be considered whether it is in consequence of those circumstances (combined, possibly, with others to be alluded to) that portions of the earth's surface which were formerly submerged, have become formed into dry land, and raised to various altitudes above the sea level; the extent of such elevation reaching, in the cases of some mountain peaks and ridges, to nearly five miles of perpendicular height.

Of course, it is not intended to be here affirmed, that the difference between the various observed tidal effects at any one place upon the globe, or between

those which are manifested at different places, is sufficient to account for those much greater changes of level under consideration; for it is clear enough that the greatest amount of any such difference is vastly too insignificant to explain them. The greatest observed amount of tidal effect occurring at any one place, as at the Bay of Fundy, for instance, where the apparent flow of water reaches to 120 feet, would, evidently, be quite inadequate for the submergence of the most ordinary of the innumerable hilly projections that exist in every part of the world. And the difference between the daily tidal effects at different places, would be still more insufficient for the purpose.

Although the manner in which the influence of the sun and moon is exercised upon the ocean is unmistakably indicated by those daily tidal manifestations, it by no means follows that the full measure or amount of that influence is thereby shown, either directly at any one place, or comparatively as between different places on the globe. The extent to which the attracting power of those luminaries affects the waters of the ocean has not in fact been yet ascertained by men of science; and, bearing in mind how numerous and complicated are the circumstances which must form part of any consideration of the oceanic effects resulting in consequence of the earth's axis being altered in the manner pointed out, the subject seems hardly capable of an absolutely exact

conclusion by means of any rigid scientific calculations or data.

That an alteration in the relative levels of the land and sea is occasioned in consequence of that oscillatory motion of the earth which has been described, seems to be incontrovertible; and, although the exact amount of it cannot be calculated or absolutely determined, yet the fact that such an alteration is thus occasioned, of itself constitutes a very strong *primâ facie* reason for believing that those great changes of level which are shown by the condition of the earth's crust to have taken place, and which form the subject of geological inquiry, were produced by that means. But when, in connexion with that fact, the numerous other circumstances which affect the question are taken into consideration, it seems impossible to conclude otherwise than that it has been, by means of the astronomical phenomenon just alluded to, that those changes of level have occurred. The following are some of the circumstances which appear to strengthen that conclusion:

(1) The globe's equatorial diameter exceeds the polar by no less than 26 miles, and therefore its form in equatorial regions projects beyond the outline of a regular sphere to the extent of 13 miles. It is thence evident that, as that mass of protuberant matter is distributed in some ratio over each hemisphere, reckoning from the equator to the poles, the distance from the centre of the earth to its surface (or from an

imaginary outline within the earth describing the periphery of the exact sphere) diminishes in the average ratio of about one mile in every seven degrees of latitude. Now, as the slow and gradual alteration in angular divergence which the earth's axis is ever undergoing in relation to the pole of the ecliptic, causes all regions upon the globe to be simultaneously changed in position with reference to the various parts of the waters surrounding the globe, which are held or suspended by the solar and lunar influence in a condition of unequal depth, the position of this protuberant mass of matter must also become changed with reference thereto. Its angle of inclination towards the ecliptical plane either increases or diminishes, and large portions of it are therefore being constantly, though very gradually, either brought nearer to or further from situations where the attracting power of the sun and moon over the waters of the ocean is exercised to the greatest extent. This circumstance alone must cause the conditions under which the numerous influences affecting the ocean are exercised to become gradually altered. Besides modifying or altering the exterior shape of the entire mass of water with which the globe is surrounded, it must surely have the effect of permanently increasing or diminishing the distance between the sea bed and the sea surface in every part of the world, and of causing some sea coasts and channels permanently to rise further above the sur-

face of the sea, and others to become more deeply immersed beneath it, to a far greater extent than is indicated by any merely tidal effect which is manifested by reason of the daily rotation of the globe.

(2) In a former section of this treatise, the earth's shape and the "igneous" characteristics of the nethermost portions of its crust have been referred to, as indicating that the materials of which our planet is composed were in a fused and ductile or plastic state; and that it was not until they had, at the surface at least, made considerable progress towards refrigeration, that they ceased to be influenced by the diurnal rotary motion, and that the earth's oblate-spheroidal form was finally and fixedly attained. These circumstances seem to warrant the inference, that the great body of water with which the globe is surrounded became deposited subsequently to the time when the globe itself had thus acquired its present form, and therefore that, irrespective of any influence the sun and moon exercise, it is, by means of the diurnal rotation, accumulated in greater depth in equatorial regions than elsewhere. Now, although any deeper accumulations of water about the equator must, so far as they are thus caused (unlike the inequality of depth occasioned by the sun and moon), continue to hold their places upon the earth, notwithstanding the position of the earth's axis becomes changed in the manner pointed out, yet it is difficult to imagine otherwise than that

they must enter into combination with the effects produced by the other influences to which the ocean is subjected, and that the causes to which the great geological changes of level are due, are thus very considerably enhanced.

(3) Another probable cause, quite independent of any other, of the waters of the ocean being permanently accumulated in greater depth in some parts than in others, is the motion of the globe round the sun. Whatever may be the manner in which the earth's gravitation or attracting power upon the ocean, in overcoming or nullifying the centrifugal impulse caused by the diurnal rotary motion, is exercised, it seems hardly conceivable that the vast rapidity with which the globe is propelled in its orbit can fail to impart a greater depth to some parts of the ocean than that by which other parts of it are characterized. It seems that the effect of the centrifugal impulse imparted by that rapid flight through space must be to concentrate the water, *i.e.*, to cause it to collect to an increased extent, in that part of the globe which lies outside its orbit and is opposite to the sun, and, more particularly, in regions lying in or near the ecliptical plane, whence, in a direction at right angles with that plane, the depth of water, so far as it is due to that cause, must gradually diminish. The consequence of the ocean being thus affected must be the production of what may be paradoxically described as a sta-

tionary "wave" of water, occupying a position in part identical with that occupied by the volume or collection of water indirectly caused by the sun's influence, alluded to in a previous section of this treatise. Like that solar mass or volume, this wave must ever continue to hold the same place with reference, not to any particular part of the solid globe but, to the surrounding heavens; and as it does not participate in those changes of position relatively therewith, which all parts of the solid earth's surface undergo by reason of the angular divergence of the earth's axis relatively with the pole of the ecliptic being increased or diminished, as the case may be, it must, to a very considerable extent, be contributive to that general condition of the ocean, to which the great changes of level under consideration are due.

(4) And if, by means of influences which are exterior to the earth, and are exercised constantly and invariably as regards both their amount or force and the position of the sources whence they emanate, the water surrounding the globe, regarded as an envelope to it, differs in shape from the general shape or outline of the globe, and is permanently attracted or drawn out into great masses in some regions, then the greatly varied character of the earth's superficial configuration is a circumstance which must, in some measure, help to produce those general results which constitute the changes of level in question. If, for instance, a part

of the earth's surface where there exists a depression of great depth and area is, by the oscillatory motion which causes the precession of the equinoxes, brought into a position where those exterior influences upon the ocean are exercised in the least degree, and where an elevated part of the earth's surface was previously situate, then, by means of the earth's gravitation, an alteration must be occasioned in the general condition of the water on the globe. A portion of the water will become transferred from one situation to another. The depression, although in its altered situation lying under a far less depth of water than that which previously covered it, will remain partially occupied by water. Although its sides and the elevations which border it may be laid bare, its bed and lower portions will continue occupied. By that change in its situation, therefore, it will have drawn off water from other regions. On the other hand, by the removal of an elevated region of the earth's surface, possibly not previously submerged, to a position where those exterior influences upon the ocean are more powerfully exercised, it may not only become submerged, or submerged beneath a greater depth of water than that under which it previously was, but be the means of displacing a large body of water, and leaving it free to obey the power of the earth's gravitation, and to flow to another situation. Or the converse of these effects may be produced. By the removal of a deep de-

pression in the earth's surface, possibly not previously occupied by water, to a situation where those exterior influences are exercised in the greatest degree, the result will be a greater depth or accumulation of water in that region than previously existed there, and water will thus be displaced from other regions. And a similar effect would follow if a comparatively elevated district lying under a shallow covering of water were replaced by one of a more elevated character. In all such events, the superficial inequalities of the globe, combined with the efforts of the earth's gravitation to establish a state of equilibrium, must be productive of a continually progressive modification or alteration in the general condition of the waters of the ocean.

To the foregoing considerations there remains to be added the evidence afforded by the aqueous rocks themselves, whose structure and superficial configuration, as well as some of their fossil contents, plainly indicate that they have been produced by operations resembling, in character, those which must have resulted from the astronomical causes described. In the following pages an attempt will be made to trace some of those probable operations. The evidence afforded by their results may be briefly stated to consist of the following items: (1) "Changes of level," exactly resembling those which are theoretically deducible from astronomical explanations, are known to be actually in progress in many parts of the world at the present

time. (2) The undisturbed manner in which, for the most part, one stratum reposes upon another, shows that the sediment of which the aqueous rocks are composed was deposited when the underlying surface was in the very position of horizontality which it now holds. (3) The contour of the present dry land has just the character that would have been imparted to it by such a gradual emergence above the water, as must have been produced by the motion which causes "precession." (4) By many of the fossil contents embedded in the aqueous rocks, it is certainly indicated that the sites of their sepulture have undergone alterations of climate, such as must have resulted from the angular divergence of the earth's axis relatively with the pole of the ecliptic having been altered.

The question is, then, are the various circumstances which have been enumerated sufficient to justify the conclusion, that the unmistakable indications which the crust of the earth presents, of its surface and the surface of the sea having been altered in position, each relatively with the other, have been occasioned by means of the oscillatory or conical motion of the earth which causes the "precession of the equinoxes"?

If there were no independent geological reasons for believing that, since the formation of the aqueous rocks, the earth's crust all over the world has not been subjected to fickle and indiscriminate upheaval, by means

of subterranean volcanic force, and if the astronomical occurrences on which the hypothesis advanced in this treatise is founded, were insufficient to account for the state in which those rocks are found to exist, even in that case it would seem more reasonable to attribute the "changes of level," which manifestly have occurred, to some gradual alteration in the circumstances by which the condition of the ocean is determined and regulated, rather than to such recent volcanic agency.

As, however, it is certainly inferible from explanations given to us by astronomers, that in some parts the water surrounding the globe is permanently collected or massed together in greater depth or quantity than it is in others, by influences which are exterior to the globe, and which never remove far from one stationary plane, there cannot be a doubt that, in consequence of that circumstance, and by means of the motion of the earth which occasions "precession," the positions of the solid earth's surface in every part of the world undergo a gradual alteration relatively with the surface of the sea. And although the extent to which the ocean is thus affected by those influences cannot be exactly calculated, yet when the unmistakable evidences which are furnished by the aqueous rocks, and indeed by the entire known portion of the earth's crust, are also taken into consideration, the conclusion seems to be inevitable, that

the astronomical occurrences which have been discussed, are amply sufficient to account for those alterations in the relative positions or levels of the land and sea surfaces which form the subject of geological inquiry, and which have amounted, in some instances, to as much as three and four, and even five miles of perpendicular height.

SECTION VIII.

THE MODE IN WHICH THE POSITION OF THE EARTH'S SURFACE BECOMES ALTERED RELATIVELY WITH THE SURFACE OF THE SEA.

The mode in which the alterations in the relative levels of land and sea occur illustrated by means of a terrestrial globe—the change of level produced in consequence of the earth's daily rotation on its axis—the permanent change of level resulting from the motion which causes the precession of the equinoxes—change in the relative levels of the coast and the sea at Bordeaux—on the northern shores of Europe—at the west coast of Greenland and other places, including the channel of the Thames upwards from the Nore—such changes are confirmed by the indications afforded by fossils, of different parts of the world having experienced alterations of climate, such as must have resulted from the position of the earth's axis being altered—Hugh Miller's opinion as to alterations of climate, and the evidences referred to by him of the British Islands having been submerged beneath the sea in former times.

It has been argued in the preceding section that it is by means of that slow oscillation or conical motion of the earth which occasions the precession of the equinoxes, and in consequence of the water surrounding the globe being permanently retained in a condition of unequal depth by the attracting power of the sun and moon, and probably by other influences, that the

surface of the earth and the surface of the sea become altered in position relatively with each other, the result in past times having been the emergence above the water of that which now constitutes dry land, and being in the present time those "changes of level" which are said by geologists to be taking place in many parts of the world. The formation of the aqueous rocks, of which the outer portion of the earth's crust is mainly composed, may also be said to be attributable, in a great measure, to the same causes.

For the purpose of tracing the manner in which, according to the theory herein advanced, those effects have been and are being produced, it is convenient to refer again to the plane of the ecliptic in which the earth's orbit is situate, as holding an absolutely fixed and unalterable place in the heavens, and to describe the alteration in position which the coasts and channels accessible to the sea undergo in consequence of the motion of the globe by which it is produced, in reference to that fixed plane.

The subject may be illustrated by means of an ordinary terrestrial globe, on which the usual circles, representing the equator and the ecliptic, are marked. By depressing the poles of the globe to the extent of $23\frac{1}{2}$ degrees, in order that the existing divergence of the earth's axis from a position of parallelism with the axis of the ecliptic, may be properly represented, and by bringing the ecliptical circle into coincidence

with the wooden horizon, the latter is made to occupy the place of the plane of the ecliptic, and the positions which the earth's axis and the plane of the equator hold with reference to that plane are thus correctly shown. Excepting the alteration produced by the motion which causes "precession" (and irrespective of that resulting from "nutation," and, possibly, some minor perturbations), the earth's axis always continues to hold that position with reference to the ecliptical plane, which plane may be regarded as absolutely stationary throughout all time.

So far as the water surrounding the globe is affected by influences which are exterior to the globe, that is, so far as its condition is regulated and determined by those influences, it may be regarded as an envelope of unequal depth or thickness, within which the globe revolves upon its axis without in any manner affecting or altering the condition of that watery envelope. By the operation of those influences, that covering or envelope has a greater depth or thickness in certain parts of it which lie in the plane of the ecliptic than elsewhere, and its depth gradually decreases in all directions surrounding those deepest parts to a distance of 90 degrees therefrom, at which distance its parts of least depth or thickness are situate.

Such being the condition of unequal depth in which the waters of the ocean are permanently maintained, notwithstanding the various motions of the globe, it is

how to be considered how it occurs that the motion of the earth which occasions "precession" causes the position or level of the sea surface in the neighbourhood of any place to become altered, relatively with the earth's surface at that place; in other words, how it is that a "change of level" is produced on any sea coast by that means.

By the rotation of the globe on its axis, every place upon the globe's surface is made to describe a circle, whose plane being parallel with the plane of the equator, diverges from a position of parallelism with that of the ecliptic to the same extent as does the equatorial, namely, 23½ degrees. Any place being selected—the sea coast at Bordeaux, for instance—it becomes apparent, on revolving the globe on its axis, that it describes such a circle.

Speaking generally, and omitting from present consideration the effects arising from the revolution of the moon in its orbit, and from the motion of the earth which produces "precession," it may be said that the circle thus described by any place ever continues to hold the same situation relatively with the surrounding heavens, including, of course, the ecliptic, and, therefore, relatively with the sources whence the influences exterior to the globe itself by which the ocean is affected, are exercised; and, in describing the circle, the place every day moves through or under the very same parts of that which has just been represented

as a kind of envelope, within which the globe revolves, and which is ever retained in a condition of unequal depth or thickness, independently of the globe itself.

As the plane of the circle holds an oblique position relatively with the ecliptical plane, in some parts of which the deepest portions of the envelope are situate, and the depth of the envelope being unequal and being graduated from its deepest to its shallowest parts, it follows, that the daily rotation of the globe causes every place to be always moving towards either the shallower or deeper parts of that envelope; and hence, the occurrence of the daily tidal manifestations which have already been described at considerable length.

Illustrating these effects by means of the terrestrial globe, it may, for the present purpose, be supposed that it is at the two points where the brass meridian intersects the wooden horizon (here again used for the plane of the ecliptic) that the water surrounding the globe has the greatest depth. In that case, the part of the circle, described by any place by means of the earth's daily rotation, at which the greatest depth of water exists (as at the time of "spring tides"), is that where it intersects the brass meridian, and where it is in nearest proximity to the ecliptical plane. Consequently, when the place arrives at that situation, "high water" will be manifested, and the same event will occur when it arrives at the exactly opposite part

of the circle. As, however, the circle lies much nearer to the ecliptic on the one side than it does on the other, it might be expected that the tidal effect manifested would be greater on its arrival in the one situation than in the other. In passing, it may be observed, that, in fact, it seldom or never happens that any one tide is of exactly the same height as that which immediately preceded it; but, as the illustration is only meant to exemplify, generally, the manner in which the water surrounding the globe is influenced by exterior circumstances, independently of the globe itself, the subject of the daily tides, which has been already dealt with, needs not to be further discussed in this place.

It is apparent, on referring again to the terrestrial globe, that, in consequence of the motion of the earth which occasions "precession," the circle described each day by every sea coast, and, in fact, by every place upon the earth's surface, is gradually and permanently either approaching nearer to, or receding further from, the ecliptical plane, and, therefore, that the sea coast itself is as gradually and permanently being made to perform its daily circuit under or through a deeper or shallower portion of the enveloping waters. The motion being such that it causes the equinoctial points to retrograde along the circle of the ecliptic, and that the poles of the earth are thereby made to describe in space either a circle or an ellipse—probably the

latter—its effect in thus permanently altering the position of any sea coast relatively with the ecliptic, and in causing its deeper immersion in or its further emergence out of the water, as the case may be, may be judged by means of the several circles marked on the globe to describe the equator, the ecliptic, and the equinoctial colure.

The effects thus produced may be stated in general terms, as follows: The dry land is formed by the emergence above the sea of previously submerged parts of the earth's surface, in consequence of the distance between them and the plane of the ecliptic being gradually increased by means of the motion of the earth, whereby "precession" occurs; and the deeper immersion of any sea coast in, or its further emergence out of, the water in its neighbourhood, is caused by the same means.

Supposing that, by such a circular or elliptical motion of the earth's axis, the equinoctial points are made to recede along the ecliptical circle, and the equator is brought into nearer proximity with it, the effect upon the coast at Bordeaux would be to raise up that coast, *i.e.*, to remove it further from the circle of the ecliptic, as delineated on the globe, and its further emergence out of the water in its neighbourhood would consequently ensue.

It would appear that a similar result must be manifested by the same means on the northern shores

of Europe, as on the coast of Norway, for instance; while, on the coast of Greenland, a contrary effect must take place, as the circular or elliptical motion of the earth's axis must cause that coast to become depressed towards, *i. e.*, to be permanently brought nearer to the ecliptical plane.

Now, the "changes of level" which are known to be actually occurring or to have recently occurred on those coasts, are just the effects which would be produced if the aforegoing astronomical explanations of their origin be correct. At Bordeaux, for instance, an inland step or cliff runs parallel with the coast for a considerable distance, and at the base of it are indications exactly similar to those now being wrought by the sea upon the cliffs which lie on a more southerly part of the same coast. This cliff, and the appearances of the land in its neighbourhood, are alluded to by geologists as showing that the country there has been elevated from a former level, at a date not very remote in a geological sense. The undisturbed condition of the material forming the rocks of the locality almost conclusively show that the elevation of the district could not have been occasioned in consequence of any violent process of "upheaval" by subterranean forces; but supposing that, notwithstanding the various motions of the solid globe, the waters of the ocean have been permanently maintained in the unaltered condition described, then

the apparent change of level in question is most reasonably explicable, for the earth's slow gyratory motion referred to, having occasioned a slowly increasing distance to intervene between that coast and the fixed plane of the ecliptic, and the coast having been thus carried in a direction in which the waters enveloping the earth diminish in depth, there must ensue all the appearances of a very gradual emergence, resulting, in the course of many centuries, in a very considerable change in that neighbourhood, in the relative positions of the water and dry land.

The elevation of the land which is known to be in progress in the north of Europe, and more particularly in Norway and Sweden, increasing too, as it does in amount towards the North Cape, is an effect that would result from the same cause. The mean rate of continuous vertical elevation is supposed to amount to about 2½ feet in a century, and it is affirmed, that it is so gradual as to be only ascertainable by careful scientific measurements compared after long intervals.*

It is said, on the other hand, that a gradual sinking of the west coast of Greenland during the last four hundred years has occurred, an effect the reverse of that which seems to be in progress at Bordeaux and other parts of Europe. Now, as illustrated by the terrestrial globe again, it appears that, in consequence of the same motion of the earth, the Greenland coast

* Sir C. Lyell's *Manual of Elementary Geology.*

must be slowly advancing towards, instead of receding from, the ecliptical plane, a process which must produce just such a gradual submergence as is actually taking place, if the waters of the ocean are thus permanently suspended in a condition of depth which gradually increases towards that plane.

Again, it is said that in South America, as in Patagonia and on the coast of Chili, are very palpable evidences of the recent action of the sea in places which are now above its level, indicating, according to the geological theory in vogue, that an "upheaval" of the land has taken place during a very modern period. On reference to the globe, however, it may be seen, that the effect that must result from the nearer approach of the equatorial plane to the ecliptical, must be the removal of that part of the South American continent to a greater distance from the ecliptical plane, and consequently (according to the hypothesis hereinbefore advanced), in a direction in which the waters of the ocean become shallower by reason of the influences by which their inequality of depth is occasioned being less powerfully exercised in that direction.

Numerous other instances might be adduced showing the correspondence between the effects manifest on coasts and channels accessible to the sea, and the approach of those coasts and channels towards, or their recession from, the ecliptical plane. The channel of the Thames is one of such further illustrations.

Along the Kentish and Essex shores of that river are the clearest indications of a gradual and permanent recession of the waters. The level surface of the land bordering the northern shore, and on those parts of the southern shore which are not included in the hard chalky formation, seem plainly to indicate the mode in which the disappearance of the water has occurred; the shallowness of the northern shore of the river towards its entrance, the smooth, level surface of a very large area upon which the waters remain during only a very small portion of each tide, the longitudinal direction of the neighbouring hills and valleys, and, in fact, the whole contour of that part of the country on either side of the river for many miles upwards from the Nore, afford very suggestive tokens of the direction in which the gradual drainage and ultimate disappearance of the waters took place, and of the water which now ebbs and flows in the present channel of the river, having gradually undergone a diminution of depth and volume, and of the same process of very slow diminution being still in progress.

It is indicated by some of the fossils which are found in the earth's crust, that all parts of the world have experienced a change of climate such as must have resulted from a slow alteration in the position which the earth's axis holds relatively with the pole of the ecliptic.

It is known, for instance, that many species of marine animals exist at the present day in places on the globe which have a very different climate, and are very far distant from those in which the fossil counterparts of those animals are found.

It was remarked by Hugh Miller, with regard to the climatal distribution of animals as well as of vegetation, that "there is nothing more fixed than species;" and he stated that certain fossil shells, which he had discovered some distance below the surface at Rothsay and other places in Scotland, belonged to species that are now only found living in climates very different from the climate of Rothsay, or of any part of Britain. A consideration of those and similar fossils, and also of the deposits in which they were found, and the contour of the land above them, led him to form the opinion, that not only was the whole of the British area and the northern hemisphere generally, very much depressed below the present level relatively with the sea surface, at the time the shells in question were deposited, but that the climate of the British Islands, as they then existed in the form of a multitudinous group or archipelago, was very different from that which now prevails in the same latitude.

Now, if the climatal condition of any place on the globe's surface principally depends, as it undoubtedly does, on the position occupied by the place

relatively with the sun, it necessarily follows, that the change of situation in regard to that luminary, which every part of the globe's surface undergoes by means of that motion or perturbation, whereby the precession of the equinoxes is produced, must be attended with a corresponding change of climate. In that respect, therefore, as in many others, the astronomical hypothesis herein advanced seems to be corroborated by actual geological deductions.

It may not be out of place to add here, that, although in some parts of his admirable popular lectures Hugh Miller alluded to "raised sea beaches" as being the result of upheaving volcanic force, applied, not gradually and equably, but in paroxysms, yet he seems to have entertained the opinion that, in the course of an enormous period, within a very brief portion of which those boreal shells of Rothsay, and the strata in which they are embedded, were deposited, the whole of the British area at first underwent a slow depression, so as to leave only the highest points exposed above the waters, and subsequently rose to its present altitude by a process of very gradual emergence.

SECTION IX.

SUB-OCEANIC OPERATIONS.

Some of the operations that are probably being carried on at the bottom of the ocean, described—as to the irregular configuration of the ocean bed being similar in character to other parts of the globe's surface—the effects produced in consequence of the projections, &c., on the submerged portions of the earth's surface being brought, by the earth's daily rotation on its axis, through or under the parts of the ocean which are retained in a suspended or stationary state—numerous surface and under currents—the abrading and disintegrating action of the ocean as manifested in river channels and on sea coasts, &c.—the ocean bed probably subjected to a similar destructive process in many places—hence the ocean depths become charged with a vast amount of sedimentary matter—the facilities presented by the ocean bed for the deposition of sediment—the gradual formation of vast aqueous deposits—the contour of the ocean bed may become somewhat altered by such deposits, but it is probable no general change of configuration takes place.

ASSUMING that the astronomical explanations concerning the tidal phenomena, and the different motions of the globe, lead to the conclusion, as they appear inevitably to do, that the present dry land of the world emerged from the water which previously covered it, not through any violent "upheaval" or expansion of the earth's crust by volcanic or other direct physical force, since it finally attained an in-

durated state, but simply by means of that gradual alteration in the direction of the earth's diurnal motion which produces the "precession of the equinoxes;" and likewise assuming that, by the same means, there is ever similarly in progress a gradual emergence of some parts of the ocean bed on the one hand, and a gradual submergence of some parts of the dry land on the other, then it may be reasonably supposed that there are now taking place, at the bottom of sea and ocean, the same kinds of operations as those whereby were produced the fossiliferous rocks which form the subject of geological discussion. An inquiry concerning a few of those probable operations may, therefore, lead to some feasible conjectures respecting the formation of the rocks in question.

That the submerged parts of the earth's surface are characterized by a configuration very much resembling that of the dry land itself, there is no doubt. It has been found, for instance, from soundings taken in different parts of the world, that the bottom of those mysterious depths is diversified by protuberances of various shape, height, and dimension, and that enormous elevations exist there which correspond in their general features with the greatest of the mountain ranges of the upper world. Such a configuration must also necessarily include valleys which differ from each other in form, depth, and area; and there probably also exist irregularities of a less conspicuous

nature with numerous kinds of depressions, undulations, and plains. The islands that so numerously stud the ocean are manifestly formed of partially submerged projections, such as the most elevated parts of a mountainous district or continent would present. The parts of the shores of our surrounding coasts, which are sometimes traceable for a considerable distance beyond the lowest ebb, so closely resemble, in their general features, the inland parts of the country, that it is difficult to imagine they form the limits of a superficial development of another character. And, excepting the supposed difference of level, on which the "upheaval" theory is based, there seems to be no reason whatever for believing that the portions of the globe's surface which lie beneath the ocean vary in any manner whatever from those which are above it, so far as the general character of their configuration is concerned.

But, whether or not the vast tracts lying under sea and ocean are in a depressed or collapsed condition, as compared with existing continents and islands, and whether or not the stony "crust" of our earth possesses the wonderful elastic capabilities which must be attributed to it if the modern upheaval theory be correct, matters not, so far as the part of the inquiry immediately in hand is concerned.

If sea and ocean are so suspended by the solar and lunar influence, that they do not wholly par-

ticipate in, and are not wholly carried round in consequence of, the earth's daily rotation on its axis, it follows that, by means of that rotary motion, the submerged or partially submerged irregularities and projections upon the globe's surface must be perpetually making their passage under or through the superincumbent waters. The displacement of enormous volumes of water must therefore ensue, and a great commotion of the oceans in all parts of the world must be thereby occasioned. By reason of those projections being brought violently into or against the stationary or suspended water, vast volumes of it must be pushed forward or aside; and, in consequence of their rushing back on either side of the advancing masses, in their effort to resume their previous condition, currents may be occasioned with a set or direction opposite to that of the earth's motion. On the other hand, the passage of the hinder or following portions of the same masses must occasion vortices in their wake; and, in consequence of the effort made by the immense volumes of the parted waters to find their former place, a current, in the direction of the earth's motion, may be caused. Such a continued motion through the waters, at an enormous speed, of the innumerable projections upon the earth's surface, some being entirely submerged, and others consisting of the continents and islands of the upper world, must occasion an oceanic disturbance of a most complicated

nature, and on a vast scale, and result in innumerable under and surface currents of different volume, direction, and velocity.

The daily revolution of the globe, however, whereby those effects are produced, is an ever recurring event. It may be therefore conjectured that the condition of the ocean, so far as it is thus occasioned, becomes, in a great measure normal, and is manifested in the well known great and minor currents which exist in different parts of the world, and, but for the changes effected in consequence of the other motions of the earth, including also those of its satellite, it is probable that those currents would become undeviatingly established.

In consequence of the waters of the ocean being subjected to the disturbing operations described, not only must numerous surface and under currents be produced, but a prodigious quantity of material must become abraded from the surface of the submerged rocks, and transported to localities where the configuration of the ocean bed is of such a character as to afford facilities for its deposition and accumulation.

The effect produced upon the rocks by water in motion is apparent on every sea coast and in every river channel. The very hardest kind of rock of which the sea shore consists in some places, and in which the channels of mountain torrents are formed

in others, becomes worn away in considerable quantities by its action. But the destructiveness of its agency is more plainly manifest in localities where the formations consist of softer materials. On some parts of our southern coasts, for instance, the chalk cliffs are being undermined by the constant washing of the waves, and broken into fragments which strew the shore, and, being mechanically dissolved by the action of the water, are formed into a kind of hard chalky mud. Where cliffs, consisting of a slight friable soil, are exposed to the attacks of the sea, as in the neighbourhood of Cromer, they become similarly dissolved and settled into an absolutely sandy form. The abrading and disintegrating effects produced by the action of water are, in short, plainly evident upon every sea coast, as well as upon the shore of every river and lake.

It is only reasonable to suppose that many parts of the sea bed are exposed to destructive operations of a somewhat similar kind, and that, by means of the lower currents of the ocean, many hard igneous formations become partially or entirely denuded of their previous sedimentary covering, while others, formed wholly of softer materials, are entirely broken up.

Hence there must be a vast amount of sediment in continual circulation in the ocean depths, consisting of the particles abraded from the hardest kinds

of rock, and of the dissolved materials of previous aqueous formations. The manner in which all this abraded and dissolved matter is precipitated to the bottom of the water must depend upon the force of the sub-oceanic currents in which it is borne, as well as upon the specific gravity of the atoms of which it is composed.

There can be no doubt that, beneath the hidden depths of the ocean, there are ranges of mountains ramifying in every direction, with corresponding valleys: there are probably, also, extensive plains and undulating regions, and mounds and hills of various dimensions; and it is likely that there also abound detached crags and masses of rock, such as exist in mountainous countries of our upper world, with abrupt and irregular precipices of bare stone, and channels, ravines, caverns, and recesses of all kinds.

Such a varied configuration must afford ample facilities for the gradual deposition of sedimentary matter in vast quantities. The water occupying depressed areas and valleys, being protected by the surrounding projections, probably remains in a quiescent state, and permits the heavier atoms, borne by the stream above, to find a resting place upon its bed, while other particles of less weight are carried to localities where the force of the current becomes still further reduced, and where, in their turn, they similarly deposit themselves. The currents being variously

affected by the rocky projections of those submerged regions, must cause the abraded matter to deposit itself in different ways—the filling up of valleys, the formation of sloping abutments to previously abrupt precipices, and other kinds of accumulation, being the result.

In these ever augmenting sedimentary accretions, innumerable living creatures of the ocean must ultimately find their graves, and a great accumulation of their fossil forms must therefore be taking place, as layer after layer of the disintegrated matter is deposited.

All these sub-oceanic operations are doubtless of a very diverse character. While the various materials of some composite rocks are reduced and separated into their constituent particles, and deposited in a more elementary form in different localities, the component atoms of several different kinds of material from other formations, having the same specific gravity, may be mingled together and deposited in layers in one place, and become formed into a composite deposition. While new formations are being created out of the materials which are set free by the destruction of previous accumulations, and while the depressions, valleys, and channels, of some districts are being filled up, other regions are being denuded of the materials with which they are covered.

But, although some alteration in the submerged

portions of the globe's surface may be caused by those operations, yet it is improbable that any such general change of configuration is thereby occasioned as to involve the destruction of the numerous granitic and other igneous projections of which the different mountain ranges and systems of the ocean depths are mainly composed, or even of many other formations of a less rigid and less durable character. The valleys of those regions may become strewed with masses of primitive or other hard kinds of rock, which are detached from the parent mountains by the direct and long continued action of enormous volumes of water, or by other causes; the sedimentary matter previously accumulated upon those mountain ranges, may become gradually removed from some of them, and the surfaces of the rocks, generally, may be very much worn by the friction of the currents passing over them; but there seems to be no reason for supposing that the vast mountain ranges which were formed during the volcanic era, while the earth's surface was attaining an indurated state, and before it became covered with water, are destroyed by those operations, mighty though they probably are.

SECTION X.

THE DEPOSITION OF SEDIMENT.

The mode in which sedimentary particles accumulate at the bottom of the sea is similar to that in which the material forming the aqueous rocks above the sea level was deposited—their deposition is equably effected so as to produce strata, which, as regards horizontality, are conformable with the underlying rocks and with each other—the stratified structure of the rocks above the sea level could not have been attained but for a similar equable settlement of the particles—the peculiarities of structure which mark those formations are to be thus accounted for.

THERE is reason to believe, then, that in consequence of the agitation and disturbance to which the waters of the ocean are constantly subjected by the causes before referred to, and of the effects thereby produced upon the submerged parts of the earth's surface, the ocean depths become charged with an enormous amount of sedimentary matter, which deposits itself wherever circumstances are favourable for its settlement, and in course of time accumulates into immense "formations."

It may be certainly assumed, that the manner in which all this sediment thus accumulates at the bottom of the ocean exactly resembles that in which the mate-

rial composing the aqueous rocks now above the sea level was deposited; therefore, any conclusions at which we are warranted in arriving as to the structure of the sub-aqueous formations now in progress, are, so far as the characteristics of structure result from the *mode* of deposition and accumulation, also applicable to those elevated deposits.

As regards the material of which any sub-aqueous formation is being constructed, it must of course depend upon a variety of circumstances, such as the nature of the rocks from which it is removed, the power of the water to separate it into its constituent particles, the specific gravity of the particles themselves, and the force of the currents by which they are borne. The thickness, as well as the regularity or conformity with each other, of the several layers or strata of which each formation consists, must also be regulated in a great measure by the same circumstances. In a region, for instance, scoured by one current, and where there are several deposits or formations, each composed of only one kind of material, but the material of each being of a different kind from that of the others, the matter abraded from these various rocks may become mingled together and formed into a composite deposition; or, where only one kind of rock, formed of composite matter, abounds, the several kinds of particles may become sorted by the action of the water, and may be borne to and deposited in different localities, all the particles

of each sort, and of a like specific gravity, being together formed into a separate homogeneous deposition. It may, in fact, be conceived that, consisting, as the earth's crust does, of an almost infinite variety of materials, an almost infinite variety of combinations may be formed therefrom, in consequence of the manner in which they are mechanically, as well, perhaps, as chemically, operated upon by the water of the ocean.

The manner in which the sedimentary particles sink to the bottom of the water, must also, in a great measure, depend upon their specific gravity, as well as upon the velocity of the currents by which they are transported from one place to another, and the condition of the water immediately over the locality in which their actual lodgment takes place.

Affected in various ways, as the water of the ocean no doubt is, by the different elevations or projections upon the submerged parts of the earth's surface, and by various circumstances, it is probable that its condition in any region is not uniform throughout its whole depth. Thus it may happen that the velocity of a current may gradually diminish from its surface downwards, or the reverse. And not only may different portions or strata of water in a region have different velocities, but possibly they may travel in different directions; and beneath vast expanses of ocean, where such various currents exist, there are probably extensive districts wherein the water is maintained in a quiescent

state, in consequence of the protection secured to it by widely separated mountain ranges. Such districts, partially or wholly protected from the ravaging effects of the vast currents flowing above them, may include large tracts of ocean bed possessing a greatly varied configuration, with elevations of considerable height, and extensive areas of a level or undulating character, as well as hills and mounds, and steep and gradually sloping prominences of all kinds.

It would be manifestly absurd to suppose that the sedimentary particles can be deposited upon any part of the ocean bed which is scoured by a current. In other words, their deposition can only take place upon the parts immediately over which the water remains in a quiescent state, in regions, for instance, such as those just alluded to as being protected by mountain ranges, and as including every kind of elevation that exists upon the surface of the earth.

Considering the atomic character of the sediment of which the sub-aqueous deposits are being constructed, and how retarded and gradual must be the descent of the particles to their resting-places, by reason of the velocity of the currents by which their transport is effected, and also how widely they must become dispersed and spread out as they approach the quiescent waters through which they finally sink; and considering also the sorting or sifting nature of the operations to which the particles are subjected between

the moment of their abrasion or removal and that of their ultimate settlement, it seems difficult to imagine otherwise than that the actual deposition of the atoms composing the sediment is effected in such a manner that they become equally dispersed or spread over the subjacent formations, and so that, in regard to horizontality, the layers or strata formed by their accumulation correspond therewith.

The strata of which the aqueous rocks, now above the sea level, are constituted, indicate conclusively that the deposition of the sedimentary particles composing them occurred thus equably. Had it not taken place in that manner, the stratified structure of those rocks could not have been attained, and the sediment must have accumulated in heaps, and have become otherwise massed and jumbled together after a very confused fashion.

The gradual accumulation of the particles uniformly with the site of deposition, that is to say, their equable distribution over the subjacent surface, however irregular its configuration, is manifested in the circumstance of each stratum being generally found to be approximately of one thickness throughout its area, but characterized by just such a deviation from absolute uniformity in that respect as would result from a variation in the scouring power of the current by which the particles had been abraded or removed from their original situation, or in the velocity of that

by which their transport had been effected; and with the further exception, that the strata are usually found to be thinned or fined down to a wedge shape towards their extremities, in consequence, probably, of the destruction of the rock (that is to say, the gradual exhaustion of the particular kind of material) out of which they were formed; in short, the form and composition of each stratum of a formation, especially such as happens to be of no great thickness, and the manner in which stratum succeeds stratum, seem unmistakably to indicate the approximately equable and uniform mode in which the atoms were cumulatively deposited.

Now, if the sediment composing the aqueous rocks in course of formation beneath the ocean, is thus gradually and equably deposited over the subjacent surface, it follows, that the configuration of any district upon which such accumulations are now taking place, does not become altered to any great extent by the formation of those sedimentary deposits upon it, however irregular it may be as regards the elevations and depressions characterizing it. In other words, the strata of which those deposits are being constructed attain a position which is conformable, as regards horizontality, with that of the underlying surface.

In submarine regions, therefore, not immediately liable to or affected by the influence of currents, where a new deposit is commenced upon a level surface, it is

to be supposed that the characteristics of a plain will be there preserved. Where widely separated and gently sloping prominences occur, the deposition of the sediment and its accumulation into laminæ and strata will not alter the original features of the locality, but will perpetuate its undulatory outline with, perhaps, a tendency towards an ultimate levelness of surface, in consequence, possibly, of a larger amount of sediment finding its way to the beds than to the sides of the intervening valleys; and, where several prominences with steeply sloping sides exist in close proximity with each other, there, too, the original configuration will be preserved with a like tendency towards an ultimate level.

And if such is the mode in which sedimentary matter deposits itself, we are furnished with means for the most reasonable explanations regarding the contorted appearance presented by many of the aqueous rocks above the sea level, on sections of them being exposed to view, and generally, also, with regard to the position of horizontality or deviation therefrom, with which those formations are characterized. If, for instance, there were to emerge above the waters a region which had consisted of steep-sided, elongated prominences, with narrow valleys or ravines between them, and which had been overlaid to a great depth by a series of strata formed of sediment thus deposited, and if a deep gorge or channel were to be afterwards

cut through the central portions of those hills by a rapid fresh-water current running at right angles with their length, or by other means, their perpendicular sections thus exposed to view must necessarily present just the twisted and contorted appearance by which many a deposit is distinguished; but if such a channel were formed in a direction parallel with the length of the hills, the aspect presented by sections of their steep sloping sides thus exposed, would be very different, as regards the apparent inclination of the strata, from that which would be revealed under the circumstances first supposed. Perpendicular sections of more undulating formations would present a like variety, as regards the deviation of their strata from the horizontal position, though in a less degree; and, in the case of a horizontally formed accumulation, that simple mode of deposition would be apparent, whatever might be the direction in which the water channel had been formed.

Although, then, sedimentary matter, on beginning to deposit itself in localities which have been previously scoured by currents, and where a great ruggedness of surface consequently exists, may accumulate in an irregular manner in the angles and cavities formed by projecting masses of the primitive rocks, and impart some degree of evenness to a previously rugged surface; and, although in consequence of the ocean bed, in different parts of the globe, being sub-

jected to a great variety of influences, the effects produced upon it are of a very diverse character; yet, as regards general results, there seems to be abundant reason for believing that the structure of formations created by the processes in operation in the ocean depths, bears a very close resemblance to that of the marine deposits found upon the continents and islands of the world. The mode in which the atoms or particles of abraded and disintegrated matter find their rest, their generally equable distribution over the surface of regions marked by all the inequalities which constitute hill and valley, the continuous accretion of the different sorts of sediment into laminæ and strata until they become piled up into vast aggregations, are operations that must result in formations similar to those of the upper world. And it seems difficult to form any other conjecture concerning the materials, structure, and superficial configuration of those subaqueous deposits, than that they would present, if a subsidence of the waters were to occur, just such appearances and characteristics as those by which the various sedimentary rocks which are the subjects of geological investigation are distinguished.

SECTION XI.

THE CURRENTS OF THE OCEAN.

It is probable that the directions of currents are periodically varied, or permanently changed, in consequence of the different motions of the earth and its satellite — the effect of the moon's revolution round the earth—seasonal variations caused by the earth's revolution in her orbit—the probable occurrence of other variations at longer intervals, in consequence of the "nutation" of the earth's axis.

If the currents of the ocean are produced in the manner suggested in some of the previous pages, that is to say, in consequence of the passage of the projecting masses on the globe's surface through the enveloping waters which are held partially or altogether in a stationary or suspended state by the solar and lunar influence, it may be assumed, that they would have attained a normal condition, and would have become invariable, but for the other motions of our planet, whereby changes and variations in the direction of the diurnal rotation, are occasioned.

And, with regard to the configuration of the earth's surface, so far as it results from the action of currents, it may be presumed that it, too, would have been finally and definitively attained, had there been

only such an invariable daily recurrence of events as must have ensued but for those changes and variations.

On a consideration, however, of the various evolutions of the earth and its satellite, it becomes plain, always supposing the ocean to be influenced by the sun and moon in the manner described, that they must produce a change or variation in some of the circumstances by which the ocean currents are occasioned, and in the sub-oceanic operations of which they are the cause.

The revolution of the moon, in her monthly journey round the earth, effects very considerable changes in the condition of the ocean in many respects; but whether its influence materially alters the circumstances to which the ocean currents, and the deposition of sediment upon the ocean bed, are attributable, matters but little for the purposes of the present inquiry, inasmuch as the lunar changes, being of perpetual semi-monthly recurrence, are not calculated to interfere with the established or normal condition, which the waters of the ocean and the ocean bed would have attained, but for those other more slowly developed movements of the earth.

By reason of that which is usually termed the "obliquity of the ecliptic," but which, as referred to the plane of the ecliptic, may be more properly described as the obliquity of the earth's axis, or of

the direction of the earth's daily rotation on its axis, every part of the globe's surface, both above and below the sea, undergoes, in the course of the earth's annual progress in her orbit, a change of position relatively with every part of the ecliptical plane. But, excepting a small variation caused by the "nutation" of the earth's axis, and by a very minute, though permanent and most important alteration, occasioned by a similarly minute alteration in the angle formed by the earth's axis (or by the plane of the equator), with the ecliptical plane, that change of position does not involve any angular alteration, and although very considerable in degree, it is only temporary, the result being that, at the end of a complete revolution of the solid globe in her orbit, every place upon its surface resumes its previous position.

Now, notwithstanding every part of the solid globe's surface thus alters its position relatively with every part of the ecliptical plane, it is at parts of the ocean which lie in or near to that plane that the solar and lunar influence ever continues to be exercised in its greatest degree, and where a greater depth of water consequently exists, and whence the depth is diminishingly graduated. The effect is, that the direction of the solid globe's daily rotation on its axis undergoes, in the course of the year, a change relatively with those deeper and shallower parts of the ocean, which, being dependent on the solar and

lunar influence, do not participate in the change. Hence the circumstances under which the projections and irregularities on the earth's surface are brought through or under the enveloping or superincumbent waters become varied, and a variation in the direction of the ocean currents is likely to be thereby occasioned in the course of the year.

Corroborative of this part of the hypothesis, to some extent at least, is the fact of which we are informed by geographers, that a variation, in the direction of some of the ocean currents, at certain seasons of the year, does actually occur, and to which may be added the circumstance alluded to in the earlier part of this treatise, that a periodical increase or variation in the depth of water is observable in the neighbourhood of some sea coasts.

The extent to which the sedimentary depositions at the bottom of the ocean may be indirectly influenced or modified, in consequence of this annual revolution of the earth in her orbit, seems to be of little importance as regards this part of the subject, as it is an event which recurs at comparatively short intervals, and it appears unlikely that it would materially affect the formation of those vast masses which require centuries for their accumulation or removal.

With respect to any effects resulting, according to the theory suggested, from that further motion or

vibration of the earth which occasions the "nutation" of its axis in a period of nineteen years, it may be remarked, that numerous instances of temporary "changes of level," in different parts of the world, have been noticed. Although, however, many phenomena concerning variations in the rise and fall of the water have been noted, yet it does not appear that long continued observations have been directed to the inquiry, whether variations, requiring periods of several years for their completion, occur with respect either to the apparent advance and recession of the sea or to temporary alterations in the direction of currents. And it may, perhaps, be drawing too much upon apparently accidental circumstances, to allude to the fluctuations to which the set of oceanic currents is known to be liable, as affording support to the conjectures which have been advanced. This however is certain, namely, that, besides the brief periodical changes already alluded to as occurring at certain seasons of every year, other alterations in the direction of those currents, are very often bringing even the best practical navigators into trouble, and that it has not yet been ascertained to what causes they are attributable.

SECTION XII.

THE GENERAL EFFECTS PRODUCED ON THE OCEAN AND THE OCEAN BED, IN CONSEQUENCE OF THE MOTION OF THE EARTH WHICH CAUSES "PRECESSION."

The earth may be regarded as a solid globe revolving within a watery envelope, which is maintained in a stationary condition by exterior influences, while the direction of the earth's daily rotary motion is slowly and gradually changed—the direction of ocean currents must become altered — the destruction of previous aqueous formations, and the deposition of new ones must also take place—the sea must appear to encroach upon some coasts, and to recede from others—the results produced can hardly become perceptible in brief periods, but in the course of ages they must be of a striking character —some of them described.

It now remains to be considered what are the probable effects produced upon the sea and ocean beds, in consequence of that slow motion which causes all parts of the earth's surface to be ever progressively undergoing a very gradual change of position relatively with the fixed heavens. And, in discussing this part of the subject, it is desirable that the manner in which the solar and lunar influences are exercised upon the waters should be still borne in mind.

It has been contended in the previous pages that, according to the teaching of astronomy, the waters of

the ocean are so influenced by those luminaries and by other circumstances, as to possess a greater depth or volume of water in certain parts which lie in or near the ecliptical plane than elsewhere, and also that those parts of greater depth (and the other parts of the ocean, so far as their depth is dependent on the sun and moon) always maintain a position which is absolutely stationary in relation to the ecliptical plane, while all parts of the earth's surface undergo a progressive change of position relatively therewith.

For the purpose of illustration in this respect, it has already been suggested that the earth may be regarded as a globe surrounded with and revolving within a watery envelope, which is maintained in a stationary condition by exterior influences, while the direction of the rotary motion of the enclosed globe is undergoing an extremely slow and gradual change, the result being, that the positions of all parts of the solid globe's surface are in a continual state of slowly progressive change, relatively with the various parts of the surrounding envelope.

Allusion has been previously made to the great disturbance of the waters surrounding the globe, occasioned by the rapid passage through them, by means of the earth's daily rotation on its axis, of the vast projections on the earth's submerged surface, resulting in numerous currents, and in the production of an enormous amount of sedimentary matter through the

abrasion or destruction of innumerable sub-aqueous deposits, and of formations exposed to the violence of such currents; results to which, probably, the semi-monthly lunar changes, the annual revolution of the earth in its orbit, and the motion which causes "nutation" also contribute.

Now, the very slow motion of the earth, so frequently mentioned in these pages, of necessity causes (in other words consists in) an equally slow and progressive change in the direction of the daily rotary motion; so that, supposing the waters surrounding our globe to be retained, wholly or in part, in a stationary condition (speaking of its condition with regard particularly to its variation of depth) by the solar and lunar, as well as by other influences, the circumstances under which the projections on the earth's surface make their passage through the enveloping waters also become changed; the variation or change of position thus undergone by the earth's surface, relatively with the surrounding heavens (and hence with the different parts of the enveloping waters), must occasion a corresponding variation or change in the manner in which the disturbance of the waters occurs. Enormous tracts of the ocean depths, previously protected by mountain ranges, may by that change in the direction of the earth's motion on its axis, become exposed to disturbing influences, and abrasion or destruction may hence occur where deposition was before taking

place; or that change may, on the contrary, bring into protected positions regions previously exposed, and where, consequently, the primitive or other rocks, thentofore subject to denudation, subsequently become covered with stratum upon stratum of sedimentary matter.

From the same cause, under and surface currents may become changed or destroyed; streams, currents, or sweeping volumes of water, may now be making their passage over or through vast basins and channels at the bottom of the sea, where the waters were before maintained by surrounding prominences in a condition of absolute calmness and quiescence; and other portions of those vast sea depths, through which rapid torrents had previously poured, may now be characterised by a placid stillness. In like manner, surface currents may be undergoing alteration, in consequence of the changed direction in which islands and continents are driven through the globe's watery envelope, by the diurnal rotation of the earth upon its axis. And while, in some parts of the world, the coasts and channels of the sea are, by the same slow motion of the earth, or change in the direction of the daily rotation, being brought permanently nearer to the ecliptical plane, and therefore into deeper portions of the waters which surround our globe, so that a slow but permanent submergence of the land, or encroachment of the sea upon the land, is there apparent, in other places they are being carried further from

the ecliptical plane, and into shallower portions of the water, whereby a gradual and permanent recession of the sea, or emergence of the land, becomes there manifested, so as to produce, apparently, the effect of "upheaval."

The extremely slow and gradual, though always progressive and absolutely certain, change in the circumstances, under which the globe's irregularly configurated surface and the waters of the ocean mutually act upon each other, the one by regulating the force and direction of currents, the other by destroying projections in some places, and conveying the sediment to others, can hardly effect within brief periods any great alteration in the condition of the ocean bed, or in the relative positions of the sea and dry land, but, continued through the ages which are assigned to geological operations, it must produce results of the most striking character. It appears, for instance, that, in certain submerged tropical regions, a chalky deposition is being formed on an extensive scale, by the matter abraded from the immense coralline formations there abounding, or by other means. In that chalky sediment, numberless marine animals must find their tomb; and while, during century after century, it is thus gradually accumulating, those regions are by the same slow motion of the earth which alters the direction of its daily rotation being carried either nearer to, or further from the ecliptical plane, that is, either towards or from a situation

in which the waters of the ocean are permanently retained in a condition of greater depth. If the sea bed is being carried from the ecliptical plane, its progress is towards regions where, in consequence of the earth's sphericity, the solar and lunar influence is less powerfully exercised and where, consequently, the earth is not covered by so great a depth of ocean, and where those previously submerged chalky formations will gradually emerge from the superincumbent waters, and ultimately form a large proportion of an apparently "upraised" continent in temperate latitudes.

And such is the change, as regards position, relatively with the different parts of the watery envelope of unequal depth or thickness surrounding our globe, which sea beds, with all coasts and channels, and all the so-called "upraised" portions of the earth's surface, must be undergoing, if the astronomical account of the solar and lunar influence upon the ocean, and of that slow motion of the earth, which is described by astronomers as resulting in the precession of the equinoxes, be correct. Those parts of the solid "crust" which are now entirely or partially submerged, must be progressing in a condition, either of deeper submergence in, or of emergence out of the superincumbent element. While in some parts of the globe, the material is being abraded from the rocks forming present sea boundaries, and a gradual encroachment of the sea upon the land is occurring, in

other regions, sea channels are becoming shallower, the sea appears to be receding, and by slow and imperceptible degrees, cliffs previously washed by the tides are left permanently dry, and, after the lapse of ages, occupy a far inland position. Similarly, may it be that vast submerged accumulations of sedimentary deposits are being broken up or being newly formed; that mountain ranges in the ocean depths are undergoing a process of denudation; or, while the upper portions of their primitive structure are being thus laid bare, vast deposits are being formed in the valleys at their bases. While one formation is accumulating from the materials of another, both may be progressing towards regions tropical, temperate, or frigid. In the various accumulating formations, the marine animals, and possibly the vegetation, peculiar to the different latitudes, are being entombed, and those deposits, when carried in the course of ages by the same slow motion of the earth into other climates, may be succeeded by others, in which other kinds or species of animals and plants may find their places.

Such are some of the probable operations to which the submerged portions of the earth's "crust" are subjected, in consequence of sea and ocean being affected by the sun and moon, and probably, by other influences, in the manner described, and of the globe's daily revolution on its axis undergoing a change in the direction of its motion. And it seems reasonable

to conjecture, that they are of an exactly similar character to those which have been in progress ever since the earth came to be first encircled with the watery element, and that the immense deposits of marine sediment, which now form so interesting a topic for geological inquiry, originated from precisely similar causes. That extremely slow, though regularly progressive character, which distinguishes as well the operations described as the causes producing them, appears to be in perfect harmony with the principle by which such of the other great operations of nature as are familiar to us, are regulated. The sub-oceanic effects which have been discussed seem, in fact, only to form a portion of the same great work, which has been gradually developing itself through the vast period comprehended in the earth's whole history.

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SECTION XIII.

THE EVIDENCES OF GEOLOGICAL EVENTS PRESENTED BY THE SUPERFICIAL CONFIGURATION OF THE DRY LAND.

In consequence of the direction of the earth's daily rotary motion being permanently altered, some parts of the earth's submerged surface must be rising towards and above the sea surface—the highest peaks and ridges of some mountain ranges would first appear, then projections of lesser altitude, and ultimately extensive tracts—the probable operations ensuing upon the emergence of any part of the ocean bed—the formation of rivers and the production of alluvium—the indications of such an emergence which are presented by the configuration of different localities—the denudation of the higher parts of elevated districts—the tokens of mountain valleys having been occupied by vast streams—the appearance of wreck and disorder presented by those valleys — indications of water having been pent up in their lower portions in the form of lakes, and of its having been subsequently drained off.

THE probable operations in progress beneath the waters of the ocean having been discussed, a few observations will now be directed to some of those evidences of geological phenomena which are presented by the superficial configuration of the dry land.

It is affirmed by writers on the subject, and, indeed, it is manifest, that the configuration of those parts of the earth's "crust" which lie above the sea level, presents just such indications as would have been

occasioned had there been a gradual subsidence of the waters. But we are informed by men of science, that the conditions under which the waters hold their place upon our globe's surface render the hypothesis of a general subsidence untenable; and the conclusion arrived at by most geologists, namely, that the earth's crust has been for ages, and is still undergoing, a process of violent, though gradual upheaval, is generally acquiesced in.

It is, however, one of the objects of the present treatise to show that the indications in question are attributable to other than either of those causes; and that the dry land is formed in consequence of the position of that portion of the earth's surface constituting it being, by means of an extremely slow though regularly progressive change in the direction of the earth's daily rotation, permanently altered relatively with the sun and moon, and brought into a situation where the influence of those luminaries upon the ocean is exercised to a diminished extent, and where, consequently, the average depth of water is less than it is in other parts lying nearer to the ecliptical plane.

Independently of the indications of the former prevalence of water over the parts of the earth's surface now forming dry land, which are afforded by the internal structure of the aqueous rocks, and by the interesting relics abounding in many of them in a fossil form, every country presents in its superficial

configuration very striking evidences of that element having disappeared from its surface, by just such an extremely gradual process as that which must have ensued had the land slowly emerged out of the earth's watery envelope, in the manner already explained.

And what, according to the hypothesis suggested, would be some of the probable effects upon any part of the globe's surface, in consequence of its position being thus gradually changed? Any region lying beneath the profound depths of the sea, in the neighbourhood of the ecliptical plane, must, by the change which the direction of the earth's daily rotation is undergoing at an almost imperceptibly slow rate, gradually approach nearer and nearer to the surface of the enveloping waters, in consequence of its being brought into positions where the waters are of less depth than in those which it previously occupied relatively with the sun and moon. As its distance from the ecliptic is increased, the influences of the ocean upon it probably become gradually changed; the higher portions of the mountain ranges will be the first to feel the effects of the upper currents of the ocean, and, as they approach a condition of emergence, may possibly cause those currents in part to change their direction, by compelling them to flow through their rocky channels.

The first tokens of some future continent presented to observers of the present day in the character of a "sunken rock," or a "dangerous reef," or a line of

rugged "breakers," may form the highest peak or ridge of some mountain system, which is thus approaching towards, or emerging above, the sea surface. Ages may elapse ere such rocks will emerge so far as to form a mid-ocean group of islands, and still vaster periods pass before their change of position will cause them to rise so high out of the water as to assume the dimensions of a continent.

It is probable that many a cluster of once ocean washed, partially sunken rocks, has thus emerged above the sea; and that, long after their emergence, the sea continued to flow in currents of different velocity and volume through the submerged channels and valleys at their bases. In consequence of the continuation of the elevating process, rocks or islands, previously appearing as if detached from each other, may have become united, by the emergence of the intervening parts of the same mountain range; projections of lesser altitude with other parts of the same district may have also gradually approached towards, and risen above, the sea level; and, at length, after the lapse of many ages, an extensive tract of dry land may have made its appearance.

In such a manner does it seem probable that portions of the earth's "crust," formerly lying at the lowest ocean depths in tropical regions, have come to emerge above the sea in other latitudes, and to form the various islands and continents of the present day.

Immediately upon any part of the globe's surface

being thus permanently elevated above the reach of the sea waves, it would become exposed to the rain and moisture of the atmosphere, which would find a lodgment in various cavities, or, making its way down numerous slopes, would become united in fresh water streams.

Immediately would begin, too, all the operations whereby the materials of which "alluvium" and fresh water formations consist, become accumulated. The surface of even the hardest rock becoming pulverized and disintegrated by exposure to the extremes of heat and cold, of dryness and moisture, and to other atmospheric influences, would be continually washed off in large quantities and borne into the streams and rivers below. Marine deposits, which had accumulated beneath the sea and had survived its assaults, would be similarly affected. The rivers flowing through the lower parts or beds of rocky valleys, whose whole breadths previous to their emergence had been occupied by swift sea currents, would become charged with the materials thus removed, which would accumulate in localities offering facilities for their doing so.

As the surface of the dry land became enlarged by the continued emergence of the same districts, a still greater amount of material would be washed therefrom by the incessant action of the rain and moisture from the clouds, and carried down and lodged at different parts of the valleys, at and about

the tidal embouchures of which it would accumulate. The emerging process continuing, mountains and hills of lesser height and magnitude, with the wider areas between them, would be brought above the sea; and from this increased surface a larger amount of drainage of fresh water would find its way into the streams and rivers, and become collected in extensive reservoirs or lakes. And, lastly, the less irregular portions of the sea bed, previously protected from the wearing action of the water by other already risen land, having now approached the surface of the sea, would become the site whereon immense quantities of sea and fresh water washings from the adjacent rocks would be deposited in the form of mounds and hills of various dimensions.

The following are some of the evidences presented by the superficial configuration of different localities, which seem to corroborate the foregoing brief sketch:

First. In all alpine districts the highest mountain peaks and ridges are entirely denuded of all the materials of which the action of the sea could deprive them; and many hill summits of other localities are similarly characterized. In those situations the primitive or other hardest description of rocks are bare and destitute of everything like a sedimentary covering. And hence, it seems reasonable to infer that their denudation occurred when they were in a submerged or partially submerged state, and when they

were consequently exposed to the full force and action of the sea and its different currents. The mountain tops being the highest projections of that region of the earth's surface in which they are situate, would, at all times until their emergence, be subject in the greatest degree to the assaults and ravages of the ocean; and the unprotected situation of many other projections of lesser altitude would render them also accessible to its violence.

Secondly. The highest valleys of mountainous regions present tokens of their having been once wholly occupied by enormous streams of great velocity. At certain parts of those valleys the sides of the mountains by which they are formed are more nearly perpendicular than elsewhere. The places thus distinguished occur at nearly regular intervals, and seem to have been subjected to greater violence than that to which other portions of the same mountains in the immediate neighbourhood had been exposed; and they present the appearance that may be supposed to have resulted from a powerful current having concentrated its force at those particular spots during lengthened periods, and from its having set obliquely upon them, in consequence of the obstacle it met with on the other side of the valley, where it received an impulse which altered its course, and caused it to rebound from the rocks at an angle nearly the same as that at which it had approached them.

Such indications are very general in the higher parts of the Swiss valleys, and are traceable for considerable distances; and they suggest the idea that the currents which once filled those rocky channels flowed in a zig-zag course, and had obliquely set against and been repelled from those particular places, and had described angles in the same manner as angles are formed by the billiard ball when impelled obliquely against the table's side. Similar appearances occur on the parts of the mountains which lie opposite to the embouchures of the great lateral valleys, where other great volumes of water may be supposed to have mingled with the main stream.

It seems feasible to suppose, according to the hypothesis suggested, that, as those mountainous districts were approaching the sea surface, they so modified the condition of the ocean in the vicinity in which their emergence was occurring, that portions of the vast currents which prevailed over extensive areas were directed into, and were made to flow through, the rocky channels thus presented to them, and that a divergence from the course previously pursued by the current was to some extent thus occasioned.

And that those valleys were once entirely occupied by powerful currents is also indicated by other signs. The bareness of surface, and the general rugged and disturbed appearance by which the mountain sides bounding the valleys are distinguished, are effects which

would probably be produced by currents of great magnitude and velocity. The isolated situation of enormous masses of rock, whose original dislodgment from the parent mountain, and whose removal to their present sites could only have been effected by the long continued application of a power such as would exist in a current of great force and volume; the numberless detached masses of smaller size, with which the valleys are bestrewed; the accumulations of surface washing in positions which would afford protection against the force of the stream; and the general aspect of wreck and disorder which characterize those Alpine valleys, are strikingly suggestive of their having been entirely filled in remote periods with streams or currents, which exercised upon the channels through which they flowed an almost irresistible disturbing power, and produced the most devastating effects.

Thirdly. All the valleys of mountainous districts through which rivers flow, present very striking indications of water having been accumulated in them in the form of lakes, and of their having become drained in consequence of the barriers at their contracted parts having been broken through by the violence of the outflowing torrent. The accumulation of sedimentary soil at those contracted parts—the levelness of the valley beds contrasted with the steepness of the mountain sides by which they are bounded—the character of the soil through which the rivers have cut or worn their present channels—the broken,

rugged, and often precipitous nature of the passages by which the river now makes its exit through those narrow channels—the horizontal lines which in some places seem to mark a former still-water margin, are some of the indications alluded to, which are traceable through all those parts of the mountain valleys through which rivers take their course.

The higher parts of a mountainous tract having emerged from the ocean in the manner described, the rain and moisture of the clouds descending upon their surface would find its way to the sea through those valleys lying above the sea surface, into which it had been drained. In the beds or bottoms of those valleys through whose entire breadth huge oceanic volumes of water had long previously swept, rivers would be thus formed, whose lower portions being directly connected with the ocean would be subject to tidal alternations; and with the emergence of larger parts of the same 'mountain' region, further portions of its valleys would also appear above the sea, and their greater width, increasing with the increasing distance from the most elevated part of the district with which they were connected, would present enlarged facilities for the outflow of the drainage.

In the mean time, however, numerous collections of surface drainage would be formed. Wherever the mountain or hill sides bounding a valley approached each other so as to narrow the passage between them, there probably would the greatest quantity of abraded

matter deposit itself. The accumulation thus occasioned would gradually increase until the bed of the valley in that part had become so much raised as to present a partial barrier against the outflow of the current, and to cause the waters thus dammed up behind it to assume the condition of a lake. From a lake thus formed by the accumulated waters of a mountain region, there would however be always an overflow into the portion of the valley immediately below it, the waters in which, being retained by a similar narrowing of the valley and by the deposition of sedimentary matter, would form another lake at a lower level than the last. And, in short, wherever a valley happened to be surrounded by extensive mountainous or hilly tracts of country, and so hemmed in as to present only a narrow egress for the waters, there would the drainage find its proper lodgment, and accumulate into the dimensions of a lake, and retain that condition as long as there remained obstructions sufficient to hinder the onward progress of the current.

And such, in fact, seems to be the mode in which the waters of many a river of the present day become pent up in the valleys through which they flow, and form a chain or series of lakes ere they finally escape from the mountain regions in which they originated, and emerge into the more uniform portions of their journey to the sea.

SECTION XIV.

THE SAME PART OF THE SUBJECT CONTINUED.

The gradual disappearance of former great currents is indicated in almost every river's course—tortuosity of streams and the effects thereby produced on their banks—the hill sides bounding main valleys through the beds of which rivers now flow, are marked in a similar manner—present river cliffs, &c., exactly resemble the high bluffs and headlands of hilly districts—the elongated shape of alluvial hills, &c., &c.—most rivers now occupy channels cut in the beds of former lakes or rivers—estuaries—the mode in which rivers are discharged into the sea—general effects upon the drainage of a country produced by the lowering of the sea level on the coast—the inferences deducible from the manner in which the dry land is characterised, are in accordance with the hypothesis advanced in preceding sections.

THE evidences of former accumulations of fresh water, and of their gradual disappearance, exist in other localities besides those which are of a mountainous character; and especially are they traceable throughout the course of every river, whatever may be the character of the region in which it originates, or through which it flows.

Every river flowing through districts formed of materials capable of being readily washed or worn away by the action of the current, may be observed to pursue a more or less tortuous course, whether the

land by which it is bordered be flat or hilly. That it should be thus characterized seems to be a necessary consequence of the abrading operations which all running streams effect. As they proceed on their way, they become charged with an increasing quantity of the soil removed from their beds and banks by the action and force of the current, the accumulated deposition of which occasions numerous obstacles and impediments in different parts of the route, whereby an altered direction is given to the onward flow of the water, and, ultimately, a winding or tortuous character is imparted to the stream.

It may be observed as a feature of every winding river, that wherever a bend or turn occurs, there the stream always sets directly upon one of the banks at a point from which it is repelled with considerable force, and where, consequently, a greater amount of abrading power is exercised. And it is usual to find that the part of a river's bank where the stream thus sets is perpendicular, and is of greater height than that immediately opposite to it, often being, in fact, formed in a hill side, against which the current has been directed in consequence of the particular configuration of the country through which the river wends its way. Such operations may be observed in actual progress on the banks of every river, and particularly in districts of a hilly or undulating character.

It may also be noticed that the hill sides forming

the main valley of a river, and immediately bordering the river's course, are almost invariably marked, at places where a bend or turn in the valley occurs, by a steepness or abruptness, just such as would have been produced had the stream flowed through the valley in considerably larger volume, and, by setting directly against those places, had washed the soil therefrom, exactly in the manner that the present reduced current is wearing away its own banks at the angles occasioned by the tortuosity of the stream.

It often happens that one side of a river is bounded, in some portion of its route, by a tract of level land, of greater or less extent, and on the other by a bank or cliff of considerable height, at or against the immediate foot of which it takes its present course. Almost every river is thus characterized as well in the parts lying above, as in those which are within the tidal range. The appearances thus presented are exactly such as may be supposed to have arisen, in consequence of the force of the stream having set against a hill side, which had formed an obstruction in the way of its natural flow, and had been partially worn away by the action of the current. In many places the stream may, in fact, be observed to be still exercising its wearing power upon the very bank against which it apparently had formerly set when it flowed in considerably greater volume, and with much greater effect. Such "river cliffs," as they may be

called, are very suggestive of great expanses of water having once prevailed in the neighbourhood in which they exist, and of the water having become gradually reduced in depth, until it had disappeared from the highest part of the hill out of which the cliff or bank was afterwards formed, when the current, being regulated by the particular configuration of the country over or in the midst of which it flowed, received an impulse, which directed its force against this hilly obstruction, and immediately began to operate upon the materials of which it consisted. It may be supposed that the water, continuing to decrease in quantity and depth, came to assume still more definitely the condition of a river or stream, which continued to set with, perhaps, increased violence, against the cliff or bank, the formation of which had been thus commenced; and, as the depth and width of the stream diminished, it may have gradually and entirely removed that part of the hill side, and have formed for itself a channel through the sedimentary material composing the bed of the previously existing larger stream or expanse of water.

Another evidence of streams of great magnitude having once existed in localities which now lie far above the level of any neighbouring river, consists in the sudden abruptness with which a portion of some hills are distinguished, while their other parts retain a descent of a very gradual and uniform character.

The parts of hills thus marked seem to have been formed into bluffs or headlands by the current setting against them with considerable force, and having carried away from those particular places larger portions of material than from others where, as it may be inferred from the gentle and uniform slope of the hill sides, the stream flowed with greater quietness and equability.

Such bluffs or headlands are apparent in nearly every hilly district through which a principal river still continues to flow; and they seem strongly to corroborate the supposition that the vastly larger current which had long previously occupied those valleys must have set against those places in the manner described.

Sometimes there may be observed to intervene between two high areas upon the hills a gently sloping or slightly curved depression, which is suggestive of the stream having lingered there after it had permanently disappeared from those more elevated parts.

The elongated shape of many alluvial and other hills is a feature indicative of their having been formed when the waters surrounding them consisted of a vast fresh water stream, and were gradually becoming reduced in depth and volume. It may be supposed that in those periods the condition of such hills was that of islands in the midst of a very gradually subsiding current, and they seem to be very closely analogous to the diminutive islands to be seen in those parts of almost every

river which are not subject to the scour occasioned by a very rapid current, or where the sluggishness of the stream, combined with its shallowness and the level character of the land through which it flows, prevents the formation or maintenance of a deep channel.

Winding amongst every system of hills, there can always be traced a principal valley, the course and general character of which presents indications of the waters having once flowed through it while their depth and volume was decreasing, and when they no longer filled the lateral channels leading into it from the higher portions of the hilly range.

In short, the form and contour of every hill and undulation singly, as well as the superficial configuration of every hilly district generally, is not only perfectly consistent with the supposition, but seems positively and plainly to indicate, that their existing characteristics were occasioned mainly by such a very gradual and progressive course of drainage.

In some of the foregoing pages allusion has been made to the indications traceable in mountainous districts, of water having in former times been pent up in many of the rock-bound valleys of those districts, and of its having been drained off, apparently in consequence of the barriers which had been instrumental in its accumulation having been broken through. Evidences of similar accumulations abound in other

districts, that is to say in many parts of every river's course, even down to its lowest extremity, where it is immediately connected with the ocean.

In many situations an extensive area on one or each side of a stream shows, by its flatness, that it was once covered by an expanse of water whose shores were formed by the neighbouring hills, while the channel of the existing stream indicates by its character that it has been made by the action of the current, since the soil through which it has been cut was deposited at the bottom of that expanse.

There sometimes occurs near the lower extremity of a river a large accumulation of water, whose existence is of course maintained in consequence of the site it occupies being lower than the surrounding land, and below the level of the neighbouring sea, with which it has free communication by means of a narrow channel or outlet.

It manifestly results from the circumstance of such a lake or estuary being freely accessible to the ocean by means of the channel through which the egress of its waters is effected, that its surface is maintained exactly at a level with that of the ocean itself; and it is equally clear that its condition in regard to the depth, area, and quantity of water constituting it, must necessarily be regulated by, and depend relatively upon, the level at which the sea surface is maintained.

It has been ascertained by experiment that the fresh water of a river, on discharging itself into the sea, does not readily mingle with the water of the latter, which finds its way for some distance up the channel, but flows out upon it in a separate stratum, even sometimes when the salt water undercurrent is running in. This circumstance is said to arise, in some measure, from the less specific gravity of the fresh water; and it seems probable, that it is also partly owing to the velocity and force attained by the out-flowing current in its descent from a higher level, whereby the effort of the sea wholly to occupy the river channel near its embouchure is partly overcome, and the influx of the salt water prevented, excepting in so far as it is capable of forcing its way up and permanently occupying the bed or bottom part of the channel.

It is obvious that, on any alteration taking place in the level of the ocean in the neighbourhood of any coast, there must ensue a corresponding change in the level of all such streams and bodies of water contiguous to that coast as possess a free communication with the sea.

And the effect upon the drainage of any country, on the coasts of which a lowering of the sea level occurs, must be similar to that which would be produced if the whole region were bodily raised above the sea. A permanent recession of the high and low water

limits must ensue; areas previously submerged only at the times of very high tides, and especially those lying near the embouchures and in the lower portions of river channels, would become permanently dry land; lakes or estuaries, situate near the sea and having a free communication with it, would ultimately become drained; the water flowing through all the valleys of the country would have to descend from a greater height ere it reached the sea; and the difference of level between the sea surface and all parts of the river courses being thus increased, and the barrier which the sea itself had previously presented at the river entrances being partially removed by the lowering of the sea level, the facilities for the outflow of the fresh water would become increased; and the drainage of the country being thereby more rapidly effected, the volumes of water constituting the various rivers would become reduced.

Inland lakes would in course of time become drained, and channels would be formed in their beds by the rivers continuing to flow through the sites once occupied by such lakes.

The rapidity of the streams being increased, a greater abrading effect would be exercised by them upon all parts of their channels, which would thus become deepened, while the banks at their sides would be increased in perpendicular height.

If the hypothesis contended for in this treatise be

correct, it follows that a very gradual and progressive change is always taking place in the level of the sea, relatively with the dry land, although the condition of the ocean remains unaltered in regard both to the quantity of water constituting it, and the spherical shape it assumes. It further follows that, although there has not occurred since our globe finally attained its present shape any general expansion or other alteration of its hard "crust," in consequence of volcanic or other internal agency, yet the islands and continents of the world have slowly emerged above the sea surface, in such a manner as to produce upon them exactly the same effects that would have resulted if either an actual subsidence of the ocean had occurred, or the dry land had been elevated by the application of enormous subterranean forces.

It is obvious, that the lowering of the sea level in the vicinity of any coast must, of necessity, affect the inland drainage, and lower the level of inland lakes and other accumulations of water, or cause them to be altogether drained off. The gradual disappearance of large collections of fresh water from numerous valleys and basins, must certainly have occurred, if the sea has receded by slow degrees, or howsoever, from present coast lines, as inland sea cliffs and other tokens show that it has done in many places. The river channels must also have been subjected to all the altering operations which a progressively changing

condition of drainage could effect. And it is of just such gradual and regularly progressive change that the whole contour of the dry land presents actual and physical evidence.

Thus does a consideration of the features by which the dry land is marked, seem to lead to a result corroborative of the theory which forms the subject matter of the present treatise, namely, that there has occurred just such a change in the level of the land and of the sea, each relatively with the other, as that which must have been produced in consequence of those very astronomical laws which influence the ocean, and regulate the various motions of the globe itself.

SECTION XV.

THE GRANITE ROCKS.

The cause of their irregular structure and configuration—their "igneous" origin implied from the character of the materials composing them, and also from the spherical form of the earth—their irregularity was imparted to them before they became indurated—the homogeneity of the granite rocks, and their position in the earth's crust—the refrigeration of the globe commenced at the surface—the earth's crust was probably raised into undulatory, hilly, and mountainous projections, in consequence of the refrigeratory influences to which it was exposed—volcanoes—it is probable that the process of refrigeration did not proceed equably in all latitudes—yet the molten, volcanic, and aqueous periods may have been in some degree contemporaneous.

An attempt has been made in previous sections to describe the circumstances which seem to indicate not only that the aqueous rocks were deposited subsequently to the time when the subjacent formations had finally assumed an irregular superficial outline, and had attained a solidified state, but also that the superficial inequalities of the globe have not been occasioned by any violent action of the subterranean volcanic forces, since the materials of which the "igneous" portion of its crust is composed, passed into their present state of hardness and rigidity.

The causes to which the aqueous or sedimentary deposits are probably attributable have already been discussed. It now remains, therefore, to inquire into the mode whereby the igneous formations attained the condition in which they are now found.

The materials constituting the whole of that small outer portion of our earth, with which only it is possible to become practically acquainted, have been divided by one of the highest authorities on the subject, into four principal sections of rocks, namely,—the "aqueous," the "volcanic," the "plutonic," and the "metamorphic." That very convenient classification is followed on the present occasion.

The rocks included in each of those divisions, excepting the aqueous, appear to be generally regarded as properly belonging to the "igneous" class. Even though there cannot be much doubt respecting the aqueous origin of most of those of the "metamorphic" section, yet the condition of the rocks comprised in it so clearly attests the action of a great degree of heat, as to justify, in some measure at least, that mode of dealing with them.

As the materials included in both the volcanic and metamorphic divisions are found to be only partially distributed over the globe, they seem to be of subordinate importance as compared with the plutonic or granite section, of which the entire nethermost portion of the earth's crust consists. The circumstances under

which the latter attained their present state will, therefore, be first considered.

The plutonic rocks, then, are described as consisting of granite of different sorts. They are supposed to have been formed at considerable depths in the earth, and to have cooled and crystallized slowly under great pressure, having been situate where the contained gases could not expand. Immense mountain ranges are found to be wholly composed of this material, and it constitutes the entire undermost portion of the earth's crust, as already stated. At its surface, in many places, other kinds of rock seem to have come in contact with it, at times when they and it were in a molten or highly heated state. In such places, therefore, it exists in a variety of conditions.

That the globe was in a fused or molten state during an early period of its existence, is to be inferred from the circumstance that the whole of its "crust" or exterior portion, excepting the "sedimentary" formations, is composed of "igneous" rocks of different kinds, the materials forming which indicate by their character, and by the manner in which they are cemented together, that they gradually subsided from such a state into their present indurated condition.

The spherical form of the earth also seems to warrant this conclusion, for it can hardly be imagined otherwise than that our planet had its shape imparted

to it, in a great degree at least, by means of its rotation on its axis, when the materials of which it was composed were in a pliable or elastic condition such as a great amount of heat would produce, but yet were so far advanced towards a state of solidity and congelation, as to possess the degree of tenacity and cohesiveness requisite to prevent them from expanding into greater equatorial dimensions than those ultimately designed for them.

It appears to be very generally thought that *since* the granites and other igneous rocks became solidified, the whole "crust" of the globe, including those rocks as well as the sedimentary formations, has been acted upon by subterranean volcanic forces, in such a manner as to produce the irregular configuration by which it is now marked. If, however, the materials of which the "crust" is principally formed, have passed from a fused or molten state through a process of gradual congelation onwards to the condition of hardness and rigidity in which they now exist, there seems to be abundant reason for believing that it was prior and not subsequent to the time when they had attained their indurated state, that they were thus acted upon by those forces; and that it is to the process of refrigeration alone that the structural as well as superficial inequalities of the igneous portion of our globe's "crust" are primarily attributable.

It seems probable, supposing the globe to have

been in a molten state during an early stage of its history, that the materials which formed its exterior portion in that period were so completely fused and mingled together as to be of a homogeneous character. It would therefore appear reasonable to expect, as a result of geological investigation, that some one particular description of rock should be found to prevail in all parts of the world. And one predominating class is, in fact, everywhere discovered beneath the other partially distributed formations; namely, the granites under consideration, which are invariably found to underlie every other kind of rock, and to occupy the lowermost portion of the earth's "crust" ever yet reached.

Although it appears that there are indications, on a limited scale, of some others of the igneous rocks having been in a fused condition at a time when the granite itself was in that state, and although the latter is sometimes found to protrude through the other formations, yet, as it is in fact the material of which the entire nethermost part of the globe's "crust" is formed, the term "primitive," so far as it used to be applied to that particular sort of rock, seems to be quite appropriate as denoting the place it occupies in the earth's chronology.

If the physical laws by which matter is now regulated were in operation when the globe was in the highly heated condition described, the process of re-

frigeration to which it was subjected must have commenced at the surface and have proceeded inwards by very slow degrees. The advance of the globe's "crust" towards a state of solidity would tend to prevent the escape of the gases which permeated the lower and inner portions of it, and which would have continued to be thrown off from every part of the surface, had not the congealing process begun. But, in consequence of their escape being thus impeded, there would be a tendency for them to accumulate in numerous places at various depths beneath the surface; and wherever the materials were in the most fused and yielding condition, thither would the gases force their way in increasing quantity, and, perhaps, form chambers or cavities by compressing the surrounding matter into a state of greater compactness or closeness of texture than that in which it was previously. In consequence of their being subjected to a very high degree of temperature, those gases or vapours would expand with such irresistible force as to overcome the weight and tenacity of the superincumbent mass of still partially ductile material, and to upraise it in such a manner as to produce projections of various heights and dimensions upon the globe, and ultimately to burst forth in flames wherever the earth's surface happened to be in the least hardened state, and least capable of restraining the vast concentrated power which the expansion of those subterranean gases exercised upon it.

The parts of the earth's "crust" which would be projected to the greatest height by the subterranean forces thus applied, would be those which had made the least advance towards solidification; and which, in consequence of their being in the most pliable and elastic condition, were, as masses, least capable of offering resistance. It seems likely, therefore, that after any district upon the globe had been thrown into a state of very irregular configuration, the peaks of its highest hills and mountains, being the parts where the subterranean forces had operated with the greatest effect, would become the vents from which the volcanic fires would ultimately make their escape, and out of which great quantities of molten matter would be ejected upon the neighbouring surface of the yet intensely heated and unindurated material which formed the crust of the globe.

Not only, however, would the ductile material of the earth's crust be upraised into a state of irregularity by the accumulation and expansion of the subterranean gases, but a contrary effect would be produced as soon as means had become established for their free emission in an ignited form; their partial exhaustion in that manner would cause the superincumbent masses of yielding matter to sink and collapse, and the cavities and depressions of different dimensions and forms thus occasioned, would add considerably to the irregularity of configuration which had been already produced.

The great difference which exists at the present day between the climates of different latitudes, warrants the conclusion, that an equability of temperature did not prevail during the period in which the globe was proceeding towards a state of solidification. It is probable that, although all parts of its crust progressed cotemporaneously towards that state, yet the process did not go on with absolute uniformity. It may have happened, for instance, that, while in some regions or localities the primitive or granite materials were yet fused and molten, the lowering of their temperature in others had so far advanced as to be productive of numerous volcanic eruptions, as well as of the hilly and mountainous protuberances and the subsequently formed depressions and cavities already al luded to.

The volcanic period may have commenced long ere the fused or molten period had closed, just in the same manner as the aqueous vapours surrounding the globe may have begun to be deposited in a condensed form, even while innumerable volcanoes were in active operation.

Such, as it may be conjectured, are some of the operations that ensued, if our globe during an early period of its existence was in a molten or intensely heated state, and if it subsequently passed through a process of refrigeration—operations that must have resulted in just such a condition of the nethermost part of the

earth's crust as that in which the primitive or granite rocks are actually found to exist. The homogeneity of those rocks, their universal presence below every other formation, and the irregularity of their structural and superficial configuration, appear to be the natural effects of operations such as those described; and to them also do the innumerable extinct volcanoes, of which traces abound in all parts of the world, seem to be unmistakably attributable.

SECTION XVI.

THE VOLCANIC ROCKS.

During the volcanic era great changes and transmutations may have occurred in the condition of the materials forming the earth's crust—the ejection of molten matter upon the granite —the character of the materials forming the volcanic rocks—conjectures as to the events conducing to many metamorphoses and complications in the condition and arrangement of the various rocks.

The rocks comprehended in the volcanic division are described as being of many different kinds, and as existing under very varying circumstances. They are said to be partial in their distribution, and to have been formed principally, if not altogether, of matter ejected in a molten state from the interior of the globe, through those volcanic vents and orifices the remains of which exist in all parts of the world.

It is probable that between the time when volcanic eruptions began to take place, in consequence of a gradual diminution of the earth's temperature, and the era when the internal fires had made considerable progress towards exhaustion, an enormous period intervened, during which great changes and transformations occurred at different depths beneath that

outer portion of the globe which then constituted its hardening crust, as well as throughout the crust itself upwards to its surface—changes and transformations that must have resulted in a most confused intermixture and arrangement of the many different kinds of material that existed at the surface, or were ejected upon it by the eruption of the volcanic forces.

In places where separate streams or masses of ejected molten matter happened to settle in the same vicinity upon the then yielding, but subsequently hardened, material of which the granite or primitive rocks are composed, the weight and pressure of that molten matter may have occasioned portions of the underlying ductile material to rise into and fill up the intermediate space, and even partially to overspread portions of the streams or masses themselves. The circumstances by which such molten matter would be liable to be affected, when ejected upon the surface of the globe, were probably very different from those under which the material previously forming the globe's outer portion became solidified. Formed possibly of different elementary materials, and consisting of comparatively insignificant masses, and being separated from the intensely heated interior by the earth's thick crust, which had perhaps become partially hardened, its temperature would become more quickly reduced than was that of the granite elements, and a much shorter period would therefore suffice for

it to settle into an indurated state. It is, therefore, not unreasonable to suppose that the character of that ejected material, when it ultimately attained such a condition, would be very different from that which distinguishes the granite formations.

In some places the materials of the earth's crust, which had been partially solidified, may have become a second time melted through exposure to an intense degree of heat newly applied, or the congealing and re-heating process may have been of frequent recurrence, or those materials may have become transformed by the action of different kinds of gases and vapours ere they were thrown out upon the earth's surface, or their character may have undergone a partial or complete chemical change after they were ejected, and while in a molten state and exposed to influences external to the earth itself.

Although, however, innumerable metamorphoses may have occurred in different places after the solidifying process had set in all over the earth, through a general reduction of temperature, yet it is probable they were confined to limited areas, and were more or less of a local character. The activity of many volcanoes was probably intermittent. Many of them may have frequently burst forth after lying dormant for lengthened periods, and the earth's surface in their neighbourhood, may have undergone considerable alterations in the intervals. It may have become

completely indurated, and its contraction by cooling may have caused in it innumerable rents and fissures, of greater or less extent, which may afterwards have become filled with other materials foreign to the original rock. The intervening space of time may have been of sufficient length to allow the aqueous vapours, and other influences external to the globe, to operate upon it. Those vapours may have become condensed, and the streams of water thereby occasioned may have conveyed vast quantities of disintegrated matter from regions of great altitude to the neighbouring valleys and plains. Sedimentary deposits of that kind, upon which molten matter ejected through renewed volcanic vents may have flowed down or been cast, thus coming in contact with intensely heated materials, would be liable to all such partial or complete transmutations as the heat was capable of effecting. And, although it is likely that no "upheavals" of any great extent took place after the granite crust of the earth had attained a thoroughly indurated state, yet they may have occurred in some localities on a limited scale, and have effected, by their mechanical force, considerable dislocation and disturbance of the superincumbent masses, such as the many violent earthquakes of historical times have probably occasioned in the neighbourhoods of their occurrence.

SECTION XVII.

THE METAMORPHIC ROCKS.

Conjectures as to their origin, and as to their transmutation while retaining some of their original characteristics—their being found in almost any position does not seem difficult to account for.

It is to be inferred, then, that the condition in which the granite rocks are found was produced in consequence of the globe's crust having been in a molten state, and having become solidified and hardened by reason of a very slowly progressive diminution of its temperature, and of the gradual exhaustion of the internal fires by means of innumerable volcanic vents which came into play as soon as the hardening process had fairly begun.

It appears also that, connected with the various kinds of rock comprised within the description of "volcanic," which form but a small proportion of the whole crust of the earth, and are only partially or locally distributed over it, there are numerous indications of those formations having come to occupy their present sites when they too were in a molten state, and of their having been deposited in the various

localities in which they are now found, not only at different times in the course of that lengthened period during which the volcanic eruptions were in full activity, but also under very varying circumstances, as regards the nature and condition of the rocks upon which their deposition took place.

A few words remain to be said concerning the metamorphic division of rocks, which are stated by geologists to possess some of the characteristics common to the other two classes, and yet to have distinctive features of their own, which preclude the supposition that they and the other igneous formations were all produced cotemporaneously, and under the same circumstances.

While, for instance, the crystalline texture of the metamorphic rocks plainly indicates that they have been subjected to an intense degree of heat, their stratified and often laminated condition renders it as clear that, before their transformation was thus effected, they had been deposited in their present sites by means of water; and, in fact, that they are attributable to a sedimentary origin.

It is now to be seen whether it is not very probable that the various circumstances in which the "metamorphic" rocks are found to exist have not resulted from operations that have ensued in consequence of the globe having been in the state of fusion which has been described.

It has already been suggested that the solidifying of the globe's outer portion, through a slow reduction of temperature, must have restrained the expansive gases which permeated the molten matter, and prevented them from making their escape at all points of the surface as they had done prior to the commencement of the congealing process, and that the accumulating gases must, by their expansive power, have raised the superincumbent masses of yielding material into a condition of great irregularity, both structurally and superficially, and ultimately have burst through the surface wherever the overlying matter was in the least coherent state, and least capable of resisting their power. It may also be supposed that, in localities where the subterranean pressure was thus removed, a partial sinking of the crust probably ensued, whereby a still greater degree of superficial irregularity was occasioned.

It seems reasonable to believe that in those remote times, as in the present, a considerable difference of temperature existed in the different latitudes, and, therefore, that the congealing process did not proceed equably over all parts of the globe's surface. While some regions were approaching a state of rigidity, others may have remained in a molten, or partially molten condition. It is likely, therefore, that the bursting forth of the volcanic fires did not occur co-temporaneously over all the globe, and that a very long period elapsed before that which may be termed

the "volcanic period" had fairly set in. In some regions, the volcanic fires may have attained full activity before they had commenced in others.

It may be supposed, however, that when numberless volcanoes had established themselves in all parts of the globe, its crust had so far attained a normal condition as to have become permanently marked and diversified by the upraising and collapsing effects of the volcanic forces.

But, although innumerable mountain ranges and hilly projections, as well as cavities and depressions of all depths and dimensions, may have been thus created, it is likely, as already observed, that a great inequality of temperature existed, even while in all parts the globe remained in an intensely heated condition. It may have been not only that the different latitudes and regions differed from each other in temperature and other circumstances, but that a like variance may have existed between the conditions of different localities of even the same regions.

Parts of the earth's crust, may, moreover, have been subjected to alternations of temperature in consequence of changes in the condition of the subterranean fires in the early stages of the volcanic era. Beneath localities where the earth's surface had attained a partially indurated condition, those fires may have become renewed, and have partially re-fused the superincumbent rocks, and from volcanoes, whose

activity had been stayed for a while, they may have burst forth anew.

During the vast period in which the whole globe remained in a too intensely heated state to allow of the deposition upon it of any humid vapours in a condensed form, its surface was probably subjected to an infinite variety of operations such as would amply account for the most intricate results as regards the nature of the materials forming the earth's crust, as well as the manner in which they combined together, and the position they came to occupy relatively with each other. And the introduction of the watery element must have given rise to a greatly increased variety of further combinations and modifications, amongst which may be included the formation of the "metamorphic" rocks.

If the globe gradually passed, in the manner already pointed out, from a molten to a refrigerated state, its temperature must, during a very long period, have been such as to prevent any vapours from condensing upon its surface, or from even accumulating within a considerable distance around it; and ages may have elapsed ere it became closely enveloped in the dense steamy atmosphere which promoted the growth of that luxuriant vegetation which forms so important a feature of the fossiliferous strata.

The circumstances out of which the various operations of nature arise, appear to be always adapted, in

the most absolutely perfect manner, for the exigencies of every change that occurs. It cannot be doubted that the physical elements were always maintained in a state of readiness to combine or separate, or adapt themselves in the manner exactly suited to the altering conditions of our planet as it advanced in its successive stages of development, and therefore it may be certainly assumed that, as soon as the globe was in such a state of temperature as to allow of the formation of vapour in its vicinity, moisture went on accumulating around it, and that the moment any part of the earth's surface had become sufficiently cool to permit those vapours to settle upon it in a condensed form, water thereupon made it appearance, and operations then commenced which, being continued through subsequent ages, have resulted in the most wonderful geological transformations.

As the cooling of the globe was effected by exterior influences, the heat emitted by it must have become diminished proportionately with the increase of distance from its surface; therefore, the regions which earliest advanced to a refrigerated state were those which had been raised to the greatest altitude by the volcanic forces, and it would be on them that water first made its appearance, supposing the globe to have been surrounded by vapours which only awaited the lowering of its temperature to enable them to settle upon it in a condensed form.

It seems likely, then, that water first made its appearance in the higher parts of mountain regions, as they were probably the parts of the earth soonest adapted for its deposition. And thereupon must have commenced all the various operations that could be effected by means of that element, in which may be included the wearing away of the surface of rocks exposed to its action; the accumulation of water in superficial cavities and other places wherever there happened to exist impediments against its flowing directly to lower levels; and its drainage into regions where its re-evaporation rapidly ensued, in consequence of the still intensely heated condition of the globe's surface there, and whither it transported great quantities of abraded matter.

The accretion of sedimentary deposits in localities remaining in a partially fused condition, occasioned by a continual inflow of water from higher regions under such circumstances, seems to be fully sufficient to account for the transformation which the substances composing some of those deposits have manifestly undergone. The intensely heated state of the subjacent rocks, the high degree of temperature thereby imparted to the superincumbent water wherein the sedimentary matter was held in suspension, the rapid evaporation of the water itself, and the hot steamy vapours attending that process, including withal the intermixture of the escaping subterranean gases, were

probably some among the numerous other agencies whereby the metamorphic formations attained their present crystalline character.

But it is not alone the transformation of the materials forming the rocks under consideration, that has to be accounted for upon the hypothesis of the former fused condition of the earth's crust. The position occupied by those formations relatively with others, has also to be included in the consideration. How came they, for instance, to occupy, in situations far above the water level, places immediately contiguous to the granite, and yet beneath the volcanic rocks?

As concerning the transformation of their component materials, so in regard to the relative positions of the rocks themselves, does it seem unnecessary to resort for an explanation to the supposition that the regions where they exist have been alternately "upheaved" and depressed since the deposits began to accumulate. On the contrary, their present condition would altogether necessarily result from the events above alluded to. The collection of water in different places on the earth was probably occurring even while numberless volcanoes were sending forth their molten volumes. But it is likely that the process made the most rapid progress in localities where the earth's surface had most advanced towards an indurated state, and where the subterranean fires

were becoming exhausted. In such places the volcanic eruptions were no doubt intermittent, and the lengthened intervals between them would afford abundant opportunity for the accretion of sedimentary matter on a very extensive scale.

It would seem, therefore, that the metamorphic and volcanic rocks being found to occupy alternate positions, one over the other, in the earth's crust, is a circumstance that has necessarily resulted from the former molten or intensely heated state of the globe, and in consequence of water having been gradually formed upon some parts of its surface while it was very slowly attaining a congealed and indurated condition.

SECTION XVIII.

SUMMARY OF PAST GEOLOGICAL OPERATIONS.

General resumé of the causes to which the structural and superficial irregularity of the earth's crust is attributable—the gradual refrigeration of the globe—the process illustrated by the cooling of a mass of molten metal.

THE observations contained in the previous parts of this treatise are founded upon the hypothesis that the apparently confused and irregular condition of the earth's crust has been produced partly in consequence of the globe having been in a molten or intensely heated state, and then subjected to gradual refrigeration, and partly by reason of the various motions of the earth itself, and the mode in which the waters enveloping it are affected by different influences, and especially those which are exercised by the sun and moon.

The subject is divisible into two parts, one relating to the origin of the "igneous" rocks, comprehending the granites, and the "volcanic" and "metamorphic" series, and the other referring to those vast aggregations of sedimentary materials which are described by geologists as the "aqueous" or fossiliferous formations.

The following is a brief summary of the circumstances which have been alluded to as being suggestive of the manner in which the structural and superficial irregularity of the earth's outer portion or "crust" has been attained, if the very general belief in its having passed from a fused to a refrigerated state be founded in fact, and if the account given by astronomers concerning the various motions of our planet, and the effect of the solar and lunar attractive power over the ocean, be also taken into consideration.

There exists strong presumptive evidence of the earth having been in a state of incandescence, and of its subsequent exposure to influences which very slowly and gradually reduced its temperature.

The reduction of temperature began at the surface, and caused the outer portion of the fused and intensely heated materials of which the globe was composed, slowly to attain a state of incipient congelation, or of coherency greater than it previously possessed, whereby the free escape of the gases which permeated those materials became impeded.

As the congealing process advanced, and as those materials became subjected to it increasingly as regards their depth from the globe's surface inwards, the restraints were also increased against the free escape of the gases, which were thus forced to seek places in or beneath the yet elastic crust, where they could most readily accumulate in the chambers or

reservoirs they formed for themselves, by compressing the surrounding materials into a state of greater density and compactness.

Those accumulating gases became affected by the intense internal heat of the globe, and they then, by their expansion, exercised a vast force upon the yet only partially solidified superincumbent matter. Having thus raised the surface into undulations and projections of various sizes and heights, the suppressed volcanic fires ultimately burst through the overlying matter wherever it happened to be in the least coherent and compact condition, and least capable of resistance.

A still greater amount of irregularity was imparted to the earth's surface by the sinking and collapsing it underwent in consequence of the escape and partial exhaustion of those expanding and igniting gases.

The materials of which the earth's crust consisted at that period were probably of a nearly homogeneous character, and although made up of an infinite variety of elementary substances, and subsequently subjected at their surface to altering influences, they ultimately resolved into the indurated condition in which the lowermost or granite formations are now found.

The advance of the globe's surface towards a state of congelation did not proceed equably. While in some latitudes it remained in such a partially fused condition as to allow the permeating gases to

escape with the utmost freedom, in others it had become so much consolidated as to result in great superficial irregularity, and in the formation of innumerable volcanic vents, through which the flames, and vapours, and molten matter were poured forth in enormous quantities from the interior of the earth.

The "volcanic" rocks consist of materials which were thus ejected in a molten state from beneath the earth's congealing "crust," while the latter was still in an intensely heated, and, possibly, in a partially ductile condition.

It was by means of these vents that the volcanic fires, which probably raged for many ages beneath the earth's gradually hardening crust, were slowly exhausted, and the reduction of the globe's heat was effected after its surface had attained a consolidated state.

Bearing in mind how immense is the size of the globe, and that its refrigeration has been effected by means of operations thus carried on at its surface, it is not difficult to conceive that for so vast a mass to attain an indurated state an enormous period must have been required, extending even to our own times, when those internal volcanic fires are still in a condition of considerable activity.

The effects which may be conjectured to have resulted from the earth's crust having undergone such a process of refrigeration, may perhaps be aptly

illustrated on a comparatively microscopic scale by those produced upon the surface of any large piece of metal casting after it has attained a state of congelation. By the process of refrigeration it acquires a superficial roughness, occasioned by innumerable minute irregularities, which are only perceptible on close examination. Not in any degree altering the general outline of the casting itself, and being, in comparison with its dimensions, utterly insignificant, those irregularities appear to be simply the result of operations effected at the surface during the progress of refrigeration, whereby the heat and vapours of the interior were carried off, and without which the metal could not have attained a congealed and hardened condition throughout its entire mass.

With regard to the earth, it seems difficult to imagine that its refrigeration could have been effected excepting by similar operations carried on at its surface, and resulting in numberless projections and irregularities whose proportions are almost infinitesimally minute as compared with the globe upon which they have been produced.

Thus, in consequence of the refrigerating influences to which the earth's crust was exposed, did it probably attain, while yet in a partially fused and ductile state, a structural and superficial irregularity which only became permanently impressed upon it when it had finally acquired a condition of complete congelation.

Although, however, that final condition was progressively effected, yet, probably, the process by which it was attained did not advance in the same ratio over all parts of the earth's surface. The materials forming the crust in some localities may have hardly become consolidated when in others the volcanic stage had fully set in, and while parts of the earth's surface elsewhere were so far reduced in temperature as to admit of the condensation upon it of the aqueous vapours which probably surrounded the globe in vast collections, awaiting the time when the state of its temperature would allow them to deposit themselves in a liquid form.

SECTION XIX.

SUMMARY OF PAST GEOLOGICAL OPERATIONS CONTINUED.

The condensation of aqueous vapours and the gradual accumulation of water upon the globe—sedimentary matter was thereby transported to, and deposited in still intensely heated localities—its conversion into metamorphic rocks—the formation of seas and oceans—submarine volcanoes and other operations would be sufficient to account for the most complicated arrangement of the different kinds of rock—an infinite variety of chemical effects were probably produced—an elimination of various substances from the materials of which the globe primarily consisted, may have taken place—upon seas and oceans beginning to be formed, chemical agencies may have at once begun to operate in connection with the accumulating water—the lasting saline property of the ocean may have been thus acquired—the gradual development of an atmosphere.

It cannot be supposed that while the globe wholly remained in the intensely heated state described, it was capable of allowing the surrounding vapours to become condensed upon it. As soon, however, as any part of its surface became sufficiently cool, they at once began to deposit themselves in a liquid form, and to flow to and collect in the localities that were most suitable for their accumulation.

It was in the most elevated parts of those regions which had been earliest subjected to the volcanic

operations before described, and had made the greatest progress towards a state of congelation, that the aqueous vapours were first deposited; and such, their earliest deposition, may have occurred while the surface of the lowermost valleys of the same regions still retained such a high degree of temperature as to cause at first the immediate evaporation of the water which flowed down upon it from the higher districts, bringing down with it great quantities of abraded matter. Layer upon layer of the sediment then went on accumulating, and, in consequence of the site of its deposition continuing in an intensely heated state, it became transformed in character, and acquired the peculiarities of texture which now distinguish the "metamorphic" formations, although it was all the while assuming a stratified condition. The deposition of water probably commenced in some latitudes long before it did so in others, but it may nevertheless have begun in many different regions of the globe at nearly the same time.

As the process of condensation advanced in those different regions, a corresponding increase in the flow of water to their lowermost plains and valleys must necessarily have ensued; and while many such localities may have retained so high a degree of temperature as to cause a vast amount of evaporation, yet they may have become permanently covered with the accumulating floods, the augmentation of which

must have occasioned the submergence of still wider areas.

The sedimentary particles, which were probably composed of various substances, and were borne down in augmenting quantities and deposited upon the sites whither the water flowed from the higher districts, then became subjected to all the transformations the heat was capable of effecting, even while they were assuming a laminated and stratified condition.

In consequence of the water thus augmenting, in an increasing ratio, it must have happened, when different accumulations of it originated in the neighbourhood of each other, that those separate accumulations became at length united; and, by the combination of many such enlarged collections, the water must eventually have increased to so vast an extent, that the centrifugal force of the earth's rotation on its axis and of its revolution in its orbit, began at length to affect it, and that the solar and lunar attractive power also began to be manifested upon it.

The causes which at first were in operation all over the globe and quite prevented the surrounding vapours from condensing upon its surface, and which continued in activity in some parts of the globe long after they had ceased in others, must have occasioned an enormous amount of evaporation when extensive regions became thus permanently submerged. But when vast bodies of water had been thus formed in

some parts of the world, those causes would no longer prevent that element from extending to other parts. It must have gone on accumulating until the seas and oceans of the globe had finally attained their destined dimensions in all latitudes, whatever may have been the condition of the parts of the earth's surface over which it thus ultimately prevailed.

Geologists seem to have arrived at the conclusion that submarine volcanic eruptions have taken place upon an extensive scale; and it seems improbable that the submergence of any part of the earth's surface would impede those or any other of the igneous operations which have been suggested as having necessarily occurred in consequence of the refrigerating influences to which the globe was exposed, whether the materials forming the crust happened, at the time of submergence, to be merely in an incipient state of congelation, or to have attained a condition of fully developed volcanic activity. It is likely, on the contrary, that some of those operations were facilitated thereby; as, for instance, when the water came to prevail over an extensive site where the crust was previously in such a fused or ductile state as to allow the gases which permeated it freely to escape from all points of the surface, the superincumbent water would not only by its weight help to repress those gases, but would also possibly, by its direct chemical action, facilitate the process of congelation

itself, and thereby hasten the volcanic effects which that process was the means of producing.

While, then, the seas and oceans in many regions were being formed, and were acquiring their greatest magnitude, the different parts of the earth's "crust" beneath them may have been in different conditions of development. In some parts it may have been in an incipient state of congelation, the granitic materials of which it consisted being still partially fused and ductile. Elsewhere the volcanic phase may have scarcely set in; or numberless volcanoes may have been in a state of full activity, and have been sending forth vast quantities of molten matter. Elsewhere, again, the earth's surface may have been in such an intensely heated state as to metamorphose the sedimentary materials which were deposited upon it in the greatest abundance, and to re-vaporize the water by which the sediment was brought down; while upon other parts, where the crust had attained its final indurated condition, the proper aqueous deposits were being formed upon a vast scale.

And if, in consequence of some regions being in a condition to permit the suspended aqueous vapours to condense upon them, when others were not thus prepared, water came to prevail over the former, and went on accumulating until it occasioned the submergence of regions which were yet in an igneous or actively volcanic state, until, in fact, it occupied as

much of the whole earth's surface as it was destined ultimately to envelope, such a result must have been attended by mechanical and chemical operations of the most complicated character and on a scale of vast magnitude.

As regards the igneous and earlier part of the aqueous formations, the operations thus carried on at the bottom of the sea may have produced upon them effects, among others, indicating that both those classes of rocks had been to some extent, cotemporaneously subjected to an intense degree of heat. Let it be imagined, for instance, that a district became submerged where the surface previously consisted of granitic materials in a partly fused and ductile state, and where considerable accretions of sedimentary matter thereupon took place; not only would the precipitated sediment at first take the form or outline of the surface upon which it was deposited, even while assuming a laminated and stratified condition, but it would also be subjected to such chemical transformation as the heat of the subjacent rocks, combined with the action of the water, could produce. Or, supposing a district to have become the scene of numerous volcanic eruptions after the water thus came to prevail upon it, and after sedimentary deposits had been formed by its means, those aqueous formations must have been similarly affected by the heat of the molten matter which overflowed upon them. In both cases both kinds of rock in con-

tact would afterwards present indications of their having been cotemporaneously in a heated condition, although their respective characteristics remained sufficiently intact as to conclusively testify that their origin occurred at different times, and was due to different causes.

In short, operations such as those alluded to as having probably occurred in consequence of the gradually congealing process which the earth's crust has undergone, would be amply sufficient to account for the different kinds of rock of which it is composed being now in a most complicated, and apparently confused, condition, so far as the places they occupy relatively with each other are concerned; and they seem to present the means of most reasonably explaining very many of the difficulties and apparent anomalies with which a consideration of the origin and history of the various geological formations is necessarily attended.

Not only, however, would mechanical effects of a most intricate character and on a stupendous scale, proceed from operations thus carried on upon the surface of the globe, during the enormous period in which it gradually advanced through its various stages of development, but it may also with reason be conjectured that an infinite variety of chemical effects were produced in as unlimited a degree. The numberless kinds of substances with which the earth's

bosom is stored, bear witness of the vast and complicated agencies that must have been at work to produce them. And although it may be utterly out of our power to trace the details of the various processes from which those substances have resulted, yet it is but reasonable to infer that they have all been eliminated from the materials of which the globe primarily consisted, by means of an infinite variety of changes, and combinations, and dissolutions, effected upon a scale of immensity.

It does not seem unreasonable hence to conjecture that, as soon as seas and oceans began to be formed, some of those chemical agencies also began at once to operate, whereby an affinity between the water and the substance with which it was destined ever after to be impregnated, was immediately awakened into activity. The great saline deposits stored so richly in the earth in very many places, may have been eliminated by chemical influences from the other materials of the crust while it was in a transition state, and perhaps collected and deposited in the form of sediment by means of the accumulating waters. At all events, one of the characteristics of the sea-water, namely, in that its saline quality is not impaired, but enhanced by evaporation, seems to suggest the probability that its saltness was acquired once and for good while the earth's watery envelope was in course of formation, and while the surface upon which it was accumulating

was capable of chemically imparting to it that needed specialty of condition.

The numerous operations to which the globe was subjected cannot have been confined only to its solid portions and its watery covering. The atmosphere with which it is surrounded, and which, as scientific men inform us, does not extend to a very great distance from its surface, must have had its origin in some of those operations. It seems probable that it became gradually formed as the earth advanced towards a condition suitable for the growth of vegetation, and that, after that state had been attained, it became still more rapidly developed by means, in part, of the purifying chemical influences which would be brought into play when extensive districts in different regions became covered with a vast amount of foliage.

Although it seems improbable that water could have been formed upon the globe while it was wholly in a molten or intensely heated state, or that vegetation was developed while innumerable volcanoes were in active operation, yet it may be reasonably conjectured that the molten, the volcanic, the aqueous, and the aërial operations were in some degree cotemporary. In the early part of the volcanic era, some portions of the globe's surface may have attained a partially refrigerated state, and been formed into innumerable projections of various heights, outlines, and dimensions; and there, very many volcanoes may,

consequently, have poured forth their vast fiery torrents, even while the "crust" elsewhere was in a nearly molten condition. The aqueous period may, in like manner, have begun in isolated regions, where the volcanic forces had become partially exhausted, even while enormous volumes of molten matter and gaseous fumes were being emitted from the volcanic vents that long afterwards continued in activity over the greater part of the world. And those stupendous operations to which the globe itself was subjected, were probably the cause of various chemical developments on an equal scale of magnitude, in the region of space immediately surrounding it, resulting in the gradual elimination of an atmosphere which increased in quantity and became more and more perfected in condition, as the period approached in which its agency would be required for ulterior purposes—a period that may have arrived when the crust of the globe had attained a cooled and an indurated state; when the ocean had been formed upon its surface; and, in short, when all things were prepared for the earliest development of that organic life with which it was designed that our earth should become occupied.

SECTION XX.

AS TO THE ALTERATIONS OF CLIMATE WHICH HAVE OCCURRED IN EVERY PART OF THE WORLD.

Upon what the comparative climatal conditions of different regions of the world mainly depend—owing to certain astronomical causes, those regions are always undergoing a change of position in relation to the sun—the nature and extent of that change—very long periods must elapse ere the alterations of climate resulting therefrom can make themselves manifest—the existence of some animals depends on a particular condition of climate—like fossil evidences in different latitudes, of former conditions of climate, show that the deposits in which they exist were not cotemporaneously formed—that conclusion corroborated by the chalk formations supposed to be now accumulating in tropical seas—the atmosphere or climate of the globe probably became gradually adapted for vegetable and animal life—some one region of the globe before any other may have been thus prepared—how animal organisms may have retained their proper climatal habitat—comparison of fossil remains found in different latitudes, is not a true test of their relative ages, or of the relative ages of the deposits in which they are buried.

THE astronomical causes to which the changes of level undergone by the sea and dry land, relatively with each other, are attributable, must also be productive in lengthened periods, of very considerable alterations in the climate of every place upon the globe's surface.

Although the climate of a place is no doubt very

much affected or modified by local circumstances, and although the permanent establishment of a particular state of atmosphere may be subordinately due to a variety of causes, yet it is manifest, from the difference between the temperatures of the tropical, temperate, and frigid zones, that the comparative climatal conditions of different regions primarily and mainly depend on the position those regions hold relatively with the sun, as determined by the sphericity of the earth; and as that position is always in a state of slowly progressive change, by means of the motion of the globe, frequently alluded to in these pages as causing each of the poles of the earth to describe a circle or ellipse in the heavens in a period of about twenty-six thousand years, and as producing the "precession of the equinoxes," it follows, that there must also be occasioned a very gradual but very considerable change of climate in all parts of the world.

To enable us to estimate the nature and extent of the alterations of climate thus caused, it may be convenient here, as on previous occasions, to mark or regard the changes of position in relation to the sun which all places in the world are ever undergoing in consequence of the motion in question, with reference to the great imaginary plane of the ecliptic, which passes through the centres of the sun and the earth, and may be supposed to hold throughout all time an absolutely immovable place in the universe.

From astronomical explanations it appears that, by reason of that motion the equatorial plane (or, rather, an imaginary circle or ring always encompassing the earth in the equatorial plane), which at present diverges from the plane of the ecliptic to the extent of about 23½ degrees, is gradually approaching the latter, and that it will in course of time coincide with it, and, after the moment of coincidence, separate from it again in a direction opposite to that by which the approach occurred, until the same degree of divergence has been attained, when the circle or ellipse described by each pole of the earth will have been completed, and a gradual approach of the two planes will be again commenced.

The effect may be otherwise described as an alteration in the direction of the earth's daily rotation on its axis, whereby all parts of the globe's surface are made to undergo a gradual change of position relatively with the surrounding heavens, in the centre of which the sun is immovably fixed.

It therefore follows, supposing the earth to have been in existence during, or longer than, that enormous period, that the circumpolar regions must have experienced all the climatal changes involved, first, in a gradual approach to the ecliptical plane to the extent of 23½ degrees, and then in a recession from it to the same extent; that is to say, they must have gradually passed from a condition of the utmost frigidity to one

possessing the more genial characteristics of temperate latitudes, and have receded through the same gradations. During the first half of the same period, the climate of regions within temperate latitudes must have gradually become more tropical, and during the remainder of it have as gradually resumed their more temperate state; and all places lying within the tropics must have experienced the alterations between a tropical and temperate, and a temperate and tropical climate, in a like measure.

By reason of the very great slowness of the changes thus ever in progress, they cannot but be absolutely inappreciable within the brief space of any one person's lifetime, or even within a period represented by several successive generations of men. Although, however, they cannot be ascertained by the actual experience of mankind, yet there exist positive evidences of very considerable climatal changes having occurred in the course of the globe's history. Besides glacial and other indications met with upon the earth's surface, its "crust" affords indisputable testimony to that effect. In the British Islands, for instance, as well as in other parts of the world, fossils of animals are found, having characteristics which do not appertain to any species or genera existing in the same latitudes; some of them, however, being identical with those now living in more northerly latitudes, and others with such as have a tropical habitat. And in-

asmuch as it is affirmed by scientific men, whose judgment upon the subject is authoritative, that the living animals whose fossil counterparts are thus found in different strata of the same locality, absolutely require for their existence a particular condition of climate, it has been concluded, that different places on the globe have experienced, in the course of very long periods, considerable climatal changes. The evidences afforded by the earth's "crust" thus corroborate the conclusion deducible from astronomical theory.

Although it is not absolutely affirmed in current geological systems, that all rocks possessing the very same characteristics and containing fossils of the same description, were produced exactly at the same time, yet those systems seem to be so far founded upon a supposition that fossils of precisely the same kind, in what situation soever existing, had a cotemporaneous origin, that the earth's crust has been tabulated into certain periods, to each of which are respectively assigned all the deposits, in whatever part of the world they may be, which completely resemble each other and contain similar fossil remains.

If, however, there be in nature a law or principle which thus confines certain animals to particular climatal habitats, it seems impossible that a cotemporaneousness of origin can, on the ground merely of the fossil remains contained in them being exactly alike, be ascribed to rocks situate in widely separated

latitudes. Ever since the globe attained a condition suitable for the development and maintenance of animal life, there must have been a diversity between the climates of places lying at greatly different distances from the equator, on either side; and when it happened, as a concomitant circumstance of a certain abiding climatal condition in any part of the world, that animals of a particular species or genus lived and flourished there, distant regions in other latitudes north or south must have been at the same time experiencing so different a degree of heat or cold, that the existence of exactly similar organisms could not have occurred. From palæontological as well as from astronomical considerations, therefore, it seems to be necessarily inferible that all aqueous deposits which exist in different latitudes either north or south, and contain precisely similar fossil remains, must have been formed in periods very remotely distant from each other.

This inference seems in some measure to be corroborated by operations which have been observed in progress in tropical seas, where accumulations of a substance having the appearance of chalk mud, are taking place on a very extensive scale. It has been surmised by a leading authority on the subject, that the apparently sedimentary matter which is being thus deposited, consists of minute animal organisms, and that the ancient chalk now found in vast abun-

dance in various latitudes, was originally composed of similar materials. If, therefore, a climate nearly or quite tropical was absolutely necessary for the production and multiplication of the microscopical organisms of which chalk is partly or wholly composed, it must have happened that the immense accumulations of that substance in northern latitudes, were at some former period within the range of tropical influences, that is to say, much nearer to the ecliptical plane than they now are.

While, then, it cannot be questioned that the different strata with their fossil relics, of which any particular aqueous formation is found to consist, must have been deposited chronologically in the order in which they are superimposed one upon another, yet there seem to be good and substantial reasons for doubting if even an approximate cotemporaneousness of origin can, on the ground merely of similarity of material, or of fossils embedded in it, be properly assigned to aqueous rocks which are situate in widely separated latitudes.

If the globe has passed through the several phases which have been described, it is probable that its atmosphere became gradually adapted for the various kinds of life that were to be called into being. During a long period it may have been surrounded by a hot steamy atmosphere, which, besides being chemically unsuited, was of so great a density as to be quite unfitted for animal life, and yet was pervious to light and

otherwise capable of affording the support required by vegetation. This at least is certain, that the development of vegetation must have preceded the appearance of animal organisms, seeing that upon it the latter are dependent for existence, and it may have been partly by means of an abundant growth of luxuriant foliage, that the atmosphere became adapted for them.

It may have happened that some one region of the globe before any other was thus prepared, and attained the condition of climate necessary for the lowest type of animal existence. In consequence of the animal organisms that were then awakened into life being dependent for their existence on a particular state of climate, it must have occurred in the course of a very long period, that the place upon the globe where they first appeared became gradually unsuited to their natures, in consequence of its being brought into an altered situation relatively with the sun, and being therefore subjected to a different climatal condition. In the meantime numberless successive generations of those organisms may have lived and died. Although, however, the region of their earliest existence may have thus become unsuitable, it does not follow that they were extinguished. On the contrary, they may have followed, or rather have kept pace geographically with, the changes which altered the climate of their original habitat, so that, in the course of time (long ages, perhaps), they may have come to occupy a region

very greatly distant from that in which they were first called into being, where, at last, the only tokens of their origin would consist of deeply buried fossils.

The circumstance that there are now found in the same locality the fossil remains of various animals, each species or genus of which must have required a particular state of climate for its existence, may, perhaps, be thus accounted for, if it be a fact that animals are subjected in the course of many successive generations, to a gradual and progressive change of geographical habitat, by reason of the law or necessity whereby they are compelled to remain within the limits of the same climatal influences.

If the preceding remarks be founded in fact, it follows that the geological events that have transpired, cannot be chronologically ascertained only by a comparison of the fossils found in one part of the globe's crust, with those discovered in another, unless it can be first determined in what region it was that animal life first made its appearance. Supposing it was really in some one region of the globe, which before any other had attained the suitable condition, that the development of vegetation first took place, and that animal forms, and subsequently the human family itself, first had their being, then it would be there that the most ancient relics of our race should be found, and that the chronology of events preceding its creation should be traceable.

Divine revelation and human history both point to the East as the part of the earth wherein the earliest evidences of mankind exist; and it may be that the same region will some day furnish the astronomer and geologist with the means of ascertaining with certainty the nature and chronology of the wonderful operations whereby the ultimate condition of our planet was attained.

SECTION XXI.

THE CONDITION OF THE GLOBE'S SURFACE PERFECTED.

Upon the requisite conditions being attained in any part of the world; the development of vegetation immediately began to take place—a long period probably elapsed before animal life was called into existence—it, too, probably appeared in some parts of the world long before it did so in others—the globe having passed through all the necessary preparatory phases, it became finally adapted as a habitation for the human race.

As soon as the conditions requisite for the maintenance of vegetable life had been attained in any part of the world, then, probably, the first germs of vegetation began to be developed. And it is reasonable to suppose that the earliest living animal forms were awakened into being immediately upon the means necessary for their support being permanently established. As in every other department, however, so is it likely, that some parts of the earth before others were in a state fitted for the development and maintenance both of vegetable and animal life, even while the whole globe, as an entire work, was advancing through successive stages towards the condition ultimately designed for it. Hence it may have come to pass that some parts of the earth became covered with the most

luxuriant vegetation very long before the development of even a single germ was effected in others.

A very long period probably elapsed after vegetation had come to prevail thus extensively in different regions, ere the condition of things upon and immediately surrounding the globe was adapted for the support of animal life on an extensive scale. In due course, however, the most insignificant of animal existences were probably called into being, first in the ocean and then upon the land, and were then succeeded by more complicated forms as soon as the circumstances necessary for their development had occurred.

In this respect, too, as in every other, it is likely that some parts of the globe had advanced to the required condition long before others; so that while some regions were teeming with moving life others may have been incapable of maintaining even the simplest animal organisms.

So enormous is the thickness of some of the deposits in which the vegetable substance constituting coal is found, that a vast period is supposed by geologists to have elapsed during the formation of those deposits, extending, as it has been surmised, even to hundreds of thousands of years. But while it happens that the portions of the earth's crust in which coal strata occur, offer better facilities for investigation than any other, the evidences they reveal of former animal existence are comparatively few and

insignificant. Such a paucity of animal organisms, especially those of the air breathing class, seems to corroborate the supposition that our planet was not suited for an extensive development of animal life until long after a most abundant vegetation had become established upon it.

In the meanwhile all the great laws and influences by which the globe and its seas and oceans are regulated, were occasioning, in the manner before pointed out, the most gradual but important changes in the condition and contour of the earth's surface.

Immediately upon the waters accumulating to a sufficient extent, they were subjected to the solar and lunar influences, which, in connection with the earth's rotation on its axis, occasioned daily tidal alternations. In course of time, when they had attained the full magnitude of seas and oceans, those other periodic, but less conspicuous variations in their condition, must have been also produced in consequence of the different perturbations or changes in the motions of the earth and its satellite. And those infinitely more gradual operations must also have commenced, which, with a slow but ever progressive change in the relative positions of the land and sea, are occasioned by reason of the earth's rotation on its axis undergoing a gradual change in its direction relatively with the surrounding heavens.

It may well be imagined that the ages during

which the operations alluded to were in progress, were amply sufficient to allow of the deposition of the enormous depth of sedimentary matter with which the earth is covered. And when it is considered how vast is the depth and area of the oceans surrounding the globe, and on what an enormous scale volcanic and other igneous agencies may have been in operation beneath them, it is not difficult to conceive that the aqueous formations should be found to consist of very numerous kinds of material.

And with regard to the structural and superficial configuration of the earth's "crust," including the igneous and metamorphic, as well as the aqueous formations, if, as it seems plainly to indicate, it has been produced by such progressive operations as those pointed out, and if the solar and lunar attractive power are exercised in the manner explained by astronomers, then may it also be concluded that the "change of level" which is observed to be in progress in different parts of the world, is occasioned by astronomical causes, and not by any physical "upheaval" of the earth's crust in consequence of subterranean volcanic forces.

Thus may the globe have passed through successive phases, until it came to be, at last, adapted as a habitation for man. That all the known processes of nature, of the smallest as well as of the largest magnitude, are effected by means of a gradual de-

velopment, adds the testimony of analogy to the more tangible and visible proofs which indicate that the globe has thus progressively attained its present condition. That ages elapsed ere the great work was consummated by the creation of the human race there are abundant evidences to prove. And the conclusion which seems to be inevitably deducible from these various considerations is, that the stupendous and complicated, and gradually progressive operations which were in the meantime taking place upon the globe's surface, were the appointed means whereby the earth attained its perfected condition, and became finally prepared as a fitting abode for the being whose creation immediately preceded God's Day of Rest.

SECTION XXII.

GEOLOGICAL DEDUCTIONS TESTED BY THE MOSAIC NARRATIVE OF THE CREATION.

It is proved by geological evidences that the earth has undergone a process of gradual development—it is reasonable to suppose a principle of gradual advancement towards a perfected condition prevailed throughout the earth's entire history—the probable earliest condition of the globe as suggested by astronomical considerations—the course of events elicited by geological investigation seems to agree with the general outline of the Mosaic narrative—there was probably a period when neither light, nor water, nor an atmosphere were present on the globe—from the Mosaic narrative a period is to be implied when neither vegetable nor animal life existed; and hence, also, when there was no light upon the earth—there being no actual averment in that narrative of water having been created, its pre-existence is to be implied—in the Mosaic narrative the formation of an atmosphere and of an oceanic collection of water, and the development of vegetation, are described in the order indicated by astronomical and geological deductions—the time when the atmosphere became sufficiently clear for the sun, moon, and stars to be apparent in the firmament was probably when ocean, air, and earth were adapted for animal life—the calling into existence of the human race subsequently to the creation of all other departments of nature, is proved by geological evidence, and is in accordance with the Scriptural narrative—concluding remarks.

With the view of testing the hypothesis advanced in the preceding sections, by the very brief narrative of events contained in the first chapter of Genesis, the following observations are added to the matters previously discussed.

It results from evidences which not only are furnished by a comparison of the different kinds of fossils with each other, but can also be elicited from the structural condition of the globe's "crust," that our earth has undergone a continuous process of development from a time when neither vegetable nor animal life existed, onwards through a period wherein the very simplest organisms which first appeared were succeeded by others having more complicated forms, those, in their turn, being followed by creations of a still higher order; and the same process of advancement being ever continued until the human race itself was called into existence.

And inasmuch as a principle of designed progress or development is deducible from the evidences thus afforded by those parts of the earth's "crust" which are accessible to investigation, it seems reasonable to conclude that the same principle has prevailed throughout the earth's entire history; as well that portion of it which can, to some extent at least, be unravelled by means of actually existing indications, as that concerning which there are no tangible or visible traces.

It is of course impossible to believe otherwise than that there was a time when "the earth was without form and void"—when, in fact, it did not exist; and if there be good ground for inferring that it originally consisted of a vast mass of ductile molten matter, as its spherical form as well as the nature of the lowermost

parts of its crust seems to indicate that it did, it is not unreasonable to suppose that it was projected into space in that state, with a centrifugal impulse which imparted to it its various motions, but yet with such centripetal restraints as confined it to the necessary orbital limits. Thus must there have been a time, too, when its first revolution on its axis, and its first journey in its orbit were begun; and if it should have happened (as to the unmathematical mind, at least, it appears not impossible that it did) that in the earlier ages of its existence, both its rotary motion on its axis, and its orbital motion through space, were vastly slower than they now are, it must of course have occurred that both the days and years of that era were proportionately longer than the present corresponding periods of time. Exact and profound as are the calculations of astronomers, and wonderful as are the results which they reveal to us, yet they do not possess any absolutely perfect means of *directly* measuring even the present velocities at which the heavenly bodies perform their various evolutions; and although it is mere surmise and conjecture, yet for anything that science can positively affirm to the contrary, there is nothing unreasonable in the suggestion that in that early stage of the earth's history, one revolution of our planet on its axis, or a day, may have literally occupied the time now consumed in even a thousand of its revolutions in its orbit.

The information given to us by astronomers concerning our planetary system leaves no room whatever for doubting that the sun existed before ever the earth was formed; and, indeed, the theory which has been supported by some learned men, namely, that our planet originally formed part of the sun itself, and was projected from it, seems entitled to more credence than does any other that has been advanced. While, however, entirely acquiescing in the truthfulness of that which astronomers assure us, as to the sun being the centre (or nearly) of our planetary system and as to its existence being necessary for the maintenance of that system, it by no means follows that the conjectures put forth by other learned men, to the effect that the Mosaic account of the creation is in conflict with that elementary astronomical fact, are entitled to belief.

Regarded as abstract propositions, the statements, "In the beginning God created the heaven and the earth," and "God said, let there be light, and there was light," command our absolute assent. Neither of them deny that the sun previously existed, nor in either is its actual creation averred, unless in "the heaven," the whole universe, including the sun and moon and all other heavenly objects, is comprehended. And if the words of the English version, "and the earth was without form and void," are interpretable, as they seem of absolute necessity to be, that the earth was non-existent, then (also supposing the first verse

to be a kind of preface to, or general predication of what follows, a supposition that seems to be as reasonable as any other) the command for the light to manifest itself holds no inconsistent place in the course of events described in the first thirteen verses of the Mosaic narrative, even though the creation of the sun itself, or of light, were meant to be implied.

It is, however, with the particulars of the earth's progress through those successive preparatory stages, towards the ultimate condition designed for it as a habitation for the human race, which are described in the sixth and following verses of the Mosaic revelation, that a geological hypothesis seems to be most capable of being compared and tested. And, without presuming to venture upon any scholastic criticism as to the exact interpretation of that account, it may be observed, that the general course of events therein very briefly described, seems to agree with that through which geological investigation conducts us.

If the globe was projected into space while it was in an intensely heated condition, the subsequent accumulation of water upon its surface and of the enormous quantity of aqueous vapour around it, are hardly to be accounted for, otherwise than by supposing that there existed in space an almost infinite amount of such vapour, or of some element out of which it could be eliminated by the globe's heat, or by some influence the globe or its motions may have awakened into

activity. And indulging in conjecture, though of a most reasonable kind, it may be imagined that during a considerable portion of the "molten period" dense aqueous vapour, combined with the gaseous fumes which emanated from every part of the earth's surface, so deeply and impenetrably enveloped the globe as to completely obscure the sun's light from it.

It is difficult to imagine otherwise than that vegetation, whose seed or germinating influence seems to be "of itself" in the earth, so spontaneously does it everywhere spring up, must of necessity have come into existence as soon as the conditions requisite for its development and maintenance were fulfilled. And as geologists discover that there are no traces whatever of either vegetable or animal forms in the lowermost portions of the earth's crust, it seems reasonable to conclude, whatever may be the circumstance to which that fact is owing, that during an early period those conditions did not exist, and that neither light, nor moisture in a condensed form, nor an atmosphere, were present upon the globe.

With respect to animal life no argument is needed to enable us to determine most certainly that it was subsequently created, seeing that its existence is maintained by means of the vegetable products of the soil.

Now, in the Mosaic account of the world's development, a period is alluded to wherein neither vegetable nor animal life were in being. For instance, after the

formation of seas and dry land is described, vegetation is said, in the 11th and 12th verses, to have been brought forth upon the earth; and, although it is not stated whether it was in consequence of the intense heat of the globe's surface, or of the obscuration of the sun's light, or of the absence of moisture and any kind of atmosphere, or of all those causes combined (and the last seems to be the most feasible supposition), that a period elapsed ere it appeared, yet it does thus positively convey to us that very information of there having been such a period, which is obtained by an investigation into the structure of the earth's crust.

It is a curious circumstance that, in the Mosaic brief description of the earth's progress through its various stages of development, there is no positive averment of water having been called into existence, or produced upon the arena of creation, and that the command "let there be," applied to other departments of nature, as "let there be light," "let there be a firmament in the midst of the waters," &c., &c., is not used in reference to that element. From the statements, "and the Spirit of God moved upon the face of the waters," and "God said, Let there be a firmament (or an expansion) in the midst of the waters, to divide the waters from the waters," its pre-existence seems to be necessarily inferible. Now, if the first of these statements is capable of being interpreted as meaning that water existed in space, as it may have done in

the form of aqueous vapour, then does the creation of a firmament or of an expansion, or its development from a prior condition of things—for the words "let there be," are capable of either interpretation—seem to describe just such a separation as an atmosphere would effect between the moisture which was suspended in space around the globe, and that which was deposited upon its surface in a condensed form.

Continuing to apply the suggestion of there having prevailed throughout the earth's history a principle of gradual advancement or development of condition, it is reasonable to suppose that, in course of time, the heat of the globe became so much diminished as to enable collections of water to form in many places upon its surface. And it is certain that if the condensation of vapour and its deposition in the form of water thus occurred, the operation of physical laws must have caused it, as it went on extensively accumulating, to spread itself upon the globe, and form upon it one partial envelope, or in other words, "to be gathered together unto one place" (such "gathering together" being called "seas"), and so that smaller uncovered portions of the globe's surface should appear in the midst of it as "dry land."

If our globe has passed through the various stages of development described in former sections of this treatise, it seems hardly conceivable that an atmosphere adapted for the support of vegetation could have

become formed until the fiery fumes and gaseous exhalations which emanated from every part of its surface in vast quantities during the molten and part of the volcanic eras, had in a great measure abated, and until a period had elapsed sufficient for a large collection of water to be formed under that gradually developing atmosphere or "expansion." It seems, however, to be reasonably deducible from the circumstances which have been frequently alluded to, that by the time the watery element came to prevail over the greater part of the world, the earth had attained a state in which the development of vegetation could occur.

Now, in the Mosaic account, the formation of such an "expansion" or atmosphere, and of a great oceanic collection of water, and also the development of vegetation, are all described exactly in the order of occurrence thus indicated by geological deductions. The development of a "firmament in the midst of the waters," whereby there came to be a separation of the waters above that medium from those below it, is described in the sixth and two following verses; while the gathering together of the waters "unto one place," and the appearance of the dry land (or in other words the formation of seas simply, for the earth, or "dry land," was already in existence), mentioned in the 9th and 10th verses, are immediately followed by the announcement in the 11th and 12th verses, of the

bringing forth of "the grass, the herb yielding seed, and the fruit tree yielding fruit after his kind, whose seed was in itself after his kind."

But, notwithstanding that some kind of an atmosphere had become developed, and that a vast accumulation of water was formed, the heat of the globe, although gradually diminishing, must have long remained so great as to have occasioned a rapid revaporization, on an enormous scale, of the water deposited upon its surface. Hence it seems probable that, during a long period, the earth was surrounded by an atmosphere which, while it was so densely steamy that the sun and the moon and the stars were entirely obscured by it, was yet of such a nature as to be pervious to light, and was so far relieved of noxious volcanic fumes as to be well adapted for the development and growth of some kind of vegetation, which contributed its chemical influences to the further purification of the aërial element. As events continued in their slowly developing course, the ocean, air, and earth became more and more prepared for the animal life with which they were to teem; and when, in consequence of a gradual diminution of the heat of the globe and of the density of the enveloping aqueous and other vapours, the atmosphere in some parts of the world had become sufficiently cleared, the sun and the moon and the stars must have become visible from the globe's surface through or in the "firmament of the

heaven," or that which formed a medium of interception between the aqueous vapours or clouds held in suspension above the earth, and the waters which had been deposited upon its surface. Until the heavenly luminaries had become visible in that firmament or blue expanse which was occasioned in consequence of the clearing of the atmosphere, it was not possible for them to form or be "lights in the firmament of the heaven to divide between the day and between the night;" nor to serve "for signs and for seasons and for days and for years." Although previously in actual existence, yet, as heavenly objects or signs visible from the earth, and as the means whereby seasons, days, and years could be marked, they certainly did not exist as long as they were totally obscured; but, as soon as the globe came to be surrounded by a transparent expanse, then, indeed, they would serve "for lights in the firmament of heaven to give light upon the earth."

To infer from the 16th and two following verses that the sun, moon, and stars are therein affirmed to have been actually created subsequently to the time when the manifestation took place of the lights mentioned in the 14th verse, or of the "light" mentioned in the 3rd verse, is not only to suppose that the writer of the 1st chapter of Genesis was ignorant of the sun being the source of light, but is forcing and straining from the words employed, a meaning which is not literally inferible from them. As an abstract aver-

ment, it is undeniable that two great lights (with the stars also) were, whensoever, made by God, "the greater light for the rule of the day, the lesser for the rule of the night;" and that He "set them (whensoever) in the firmament of the heaven to give light upon the earth, and to rule over the day and over the night, and to divide the light from the darkness;" and it is reasonable to believe that the time when those luminaries were capable of fulfilling the purposes recited in verses 14 to 19, for which, among others, they had been whensoever created, was the time when the ocean, air, and earth had attained a condition of fitness for the development and support of animal life. According to geological deductions, that time could not have arrived until long after the emission of volcanic fires and gases had subsided over the greater part of the globe, nor until the condensation of aqueous vapours had occurred on an enormous scale, and an atmosphere had been in some measure developed; nor until the globe had so far attained a completed physical state that an oceanic collection of water had been formed, and vegetation had made some progress; in short, not until the various operations of nature had been so far consummated that the vivifying influence of the sun's light and heat could be beneficially exercised upon the soil of the dry land, and upon the waters of the ocean, and upon the atmosphere surrounding the globe.

And the Mosaic account comprised in the first nineteen verses of Genesis, regarded as a general outline of events which occurred in the history of our globe, up to the period when the waters had attained a condition adapted for the "creeping creature that hath life," and when the "face of the firmament of heaven" became suited "for fowl to fly therein," seems to agree exactly with the revelation which the structural condition of the globe's crust presents, when considered in connection with some of the leading physical laws by which the planet itself, and the air and water surrounding it, are regulated.

The earth's crust does not seem to have yet afforded to geologists sufficient information to enable them to form any conclusion as to whether the earliest palæontological records consist of vegetable or of animal organisms, or of denizens of water, land, or air; if, however, water was forming and collecting during a long period, while the volcanic fires were expending themselves and becoming gradually exhausted, it seems reasonable to suppose that after vegetation had appeared, and an atmosphere had become developed, the earth's great oceanic girdle would be adapted for the life with which it was to teem, at least as soon as the air, and before the dry land itself was similarly prepared. And the course of events described in the Mosaic account coincides with that geological conjecture, for the verses (20, 21, and 22,) which describe

the bringing forth in the waters and in the air, of the inhabitants proper to those elements, immediately precede those which relate the creation of the more complicated and more fully developed animal organisms of the dry land.

Finally, it is incontestably and absolutely established by the evidences of geology, that the calling into existence of the human race occurred subsequently to the creation of all other creatures, including "cattle and creeping thing, and beast of the earth;" subsequently, in fact, to the creation of all the departments of nature with which we are acquainted. Although it happens that the period during which mankind has occupied the earth is shown, geologically, to be almost as nothing in comparison with those vast ages in which less important beings previously lived and died, and although discussions are sometimes raised as to the agreement of such a lengthened anterior antiquity with the alleged shorter periods said to be described in Scripture, yet the fact remains, that, according to both the geological and Scriptural revelations, the making of man in the image of God, to "have dominion over the fish of the sea, and over the fowl of the air, and over the cattle, and over all the earth," was the crowning act whereby the Divine Beneficence consummated and perfected His marvellous creation.

Thus, then, from the effects produced by some of the astronomical influences to which our planet is sub-

jected, and from the evidences afforded by many of the structural characteristics of its crust, it is deducible that the earth has passed through successive phases of development from a very early stage up to the period of the creation of mankind. The result thus obtained includes only the most prominent phenomena, and with the Mosaic narrative contained in the twenty-four earliest verses of Genesis, it seems to be in very close agreement, in regard both to the nature of the events themselves, and to the chronological order of their occurrence. And while, on the one hand, the conclusion arrived at requires no straining of the language of Scripture, and is not dependent upon an inferential interpretation of it, it may be observed on the other, that the charges of inconsistency with well known astronomical facts, and of other scientific inaccuracies, with which that narrative is sometimes assailed, are not sustainable by the plain and direct averments contained in it, but are really founded upon inferences which must be acquiesced in before the course of reasoning adopted in support of those charges can be properly entered upon.

THE END.

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